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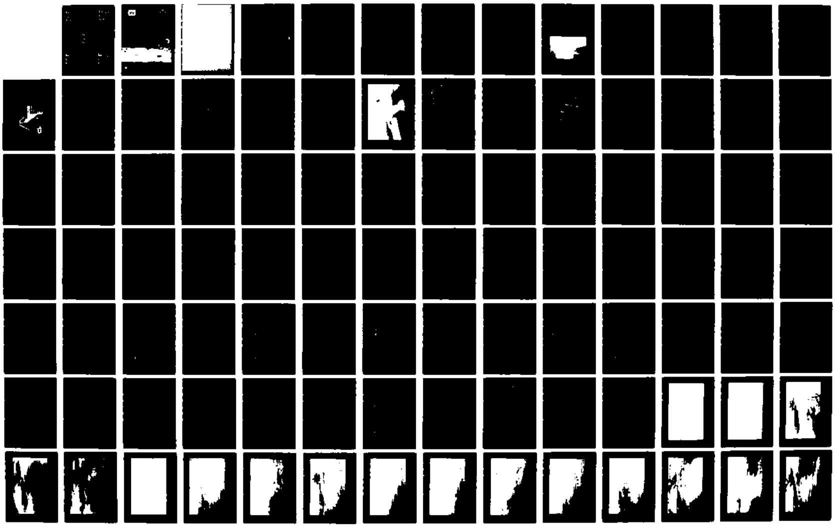

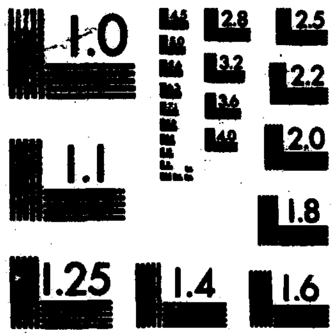

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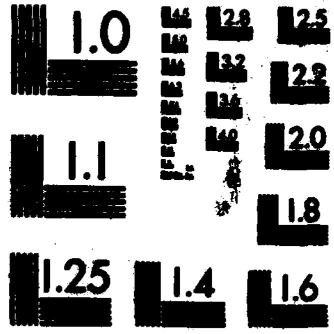

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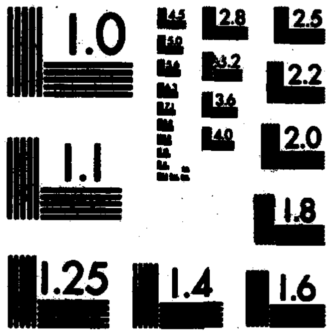

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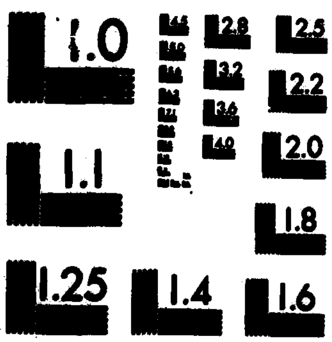

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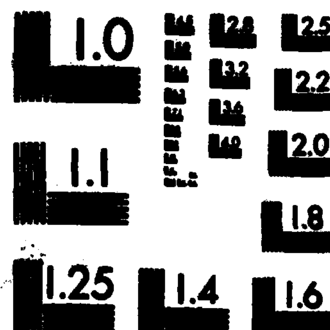

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TECHNICAL REPORT HL-82-17

DESIGN FOR WAVE PROTECTION AND PREVENTION OF SHOALING, GENEVA-ON-THE-LAKE SMALL-BOAT HARBOR, OHIO

Hydraulic Model Investigation

by

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August 1982

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer District, Buffalo
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A 1:60-scale undistorted hydraulic model of the lower reaches of Cowles Creek, the Ohio shoreline to the east and west of the creek mouth, the proposed small-boat harbor, and sufficient offshore area in Lake Erie to permit generation of the required test waves was used to investigate the design of certain proposed breakwater configurations with respect to wave protection and shoaling. The proposed improvements, as authorized in House Document No. 91-402, consisted of (a) breakwaters in Lake Erie, aggregating about 1,400 ft in length, with a riprapped spending beach between the entrance channel and the inner end of the west breakwater; (b) a 1,000-ft-long entrance channel, varying from 180 to 100 ft in width, 8 ft deep for the outer 500 ft and 6 ft deep for the inner 500 ft, extending from the 8-ft contour in the lake into the dock channel; (c) a 1,500-ft-long, 100-ft-wide dock channel, 6 ft deep, widened to 200 ft at the junction

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20. ABSTRACT (Continued)

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with the entrance channel; and (d) development of recreational facilities. ~~This~~ plan was subsequently modified ~~in the Reformulation Phase I General Design Memorandum study~~ to include: (a) breakwaters in Lake Erie aggregating about 1,050 ft in length; (b) an 800-ft-long entrance, 100 ft wide and 8 ft deep; (c) interior channels aggregating about 1,700 ft in length, 100 ft wide and 6 ft deep; (d) a small-craft refuge area totaling about 0.9 acre in size; (e) a mitigation plan including a water control structure, creation of about 5 acres of new wetlands, and expansion of an existing island to favor the establishment of waterfowl; and (f) development of related recreational fishing facilities. The reformulated plan was the one tested in the model study. A 60-ft-long wave generator, crushed coal sediment tracer material, a model circulation system, and an Automated Data Acquisition and Control System were utilized in model operation. It was concluded from test results that:

a. For existing conditions, sediments and currents along the shoreline in the vicinity of the proposed harbor may move in either direction (east or west) depending on the incident wave direction.

b. With the proposed harbor installed with no breakwaters (Base Test), rough and turbulent wave conditions existed in the harbor entrance during periods of storm-wave attack.

c. With the proposed harbor installed with no breakwaters (Base Test), sediment deposited in the entrance channel.

d. For the originally proposed improvement plan (Plan 1), significant overtopping of the breakwaters occurred resulting in excessive wave heights in the entrance and mooring areas.

e. Of the improvement plans tested under initial test conditions (maximum swl of +4.4 ft), Plan 2F (150-ft extensions of the +8 ft elevation east and west breakwaters) appeared to be optimal with respect to wave protection, orientation of the navigation entrance, and construction costs (although several test plans met the established wave-height criteria).

f. Of the improvement plans tested with the revised maximum swl of +5.3 ft, Plan 2H (200-ft extensions of the +8 ft elevation east and west breakwaters) appeared to be the most desirable with respect to wave protection.

g. Discharges from the wetland area (adjacent to the proposed small-boat harbor) had little effect on wave heights in the harbor entrance for Plan 2H.

h. Sediment accumulated against the outside of the breakwaters of Plan 2H, but did not enter the harbor entrance for any wave conditions tested.

i. To prevent erosion and/or undermining of the water control structure, a revetment should be installed, or the structure should be constructed after the breakwaters are installed and the shoreline in the area stabilizes.

j. To prevent waves from flanking the breakwaters, berms (el +12) tying the shoreward ends of the breakwaters to higher ground were required.

k. Waves in the harbor generated by the model boat (boat wake) dissipated quickly and caused no standing wave problems in the harbor.

PREFACE

A request for a model investigation of the proposed Geneva-on-the-Lake Small-Boat Harbor, Ohio, was initiated by the District Engineer, U. S. Army Engineer District, Buffalo (NCB), in a letter to the Division Engineer, U. S. Army Engineer Division, North Central (NCD), dated 8 February 1979. Authorization for the U. S. Army Engineer Waterways Experiment Station (WES) to perform the study was subsequently granted by the Office, Chief of Engineers, U. S. Army. Funds were authorized by NCB on 13 September 1979, 20 March 1980, 10 September 1980, and 1 December 1980.

The model study was conducted at WES during the period November 1980-August 1981 under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory; Mr. F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory; Dr. R. W. Whalin, Chief of the Wave Dynamics Division; and Mr. C. E. Chatham, Jr., Chief of the Wave Processes Branch. Testing was performed by Messrs. H. F. Acuff and L. A. Barnes, Civil Engineering Technicians, with the assistance of Messrs. R. E. Ankeny, Computer Technician, and L. L. Friar, Electronics Technician, under the supervision of Mr. R. R. Bottin, Jr., Project Manager. This report was prepared by Mr. Bottin.

Prior to the model investigation, Mr. Bottin visited Geneva-on-the-Lake, Ohio, to inspect the prototype site. During the course of the investigation, liaison between NCB and WES was maintained by means of conferences, telephone communications, and monthly progress reports.

Messrs. Larry Hiipikka, Charlie Johnson, and Dave Roellig of NCD and Messrs. Don Liddell, Charles Gilbert, Kenneth Hallock, Denton Clark, John Zorich, Dick Aguglia, and Ms. Joan Pope of NCB visited WES to observe model operation and participate in conferences during the course of the model study.

Commanders and Directors of WES during the conduct of this investigation and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
cubic feet per second	0.02831685	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per square metre
square feet	0.09290304	square metres
square miles (U. S. statute)	2.589988	square kilometres
tons (2,000 lb, mass)	907.1847	kilograms

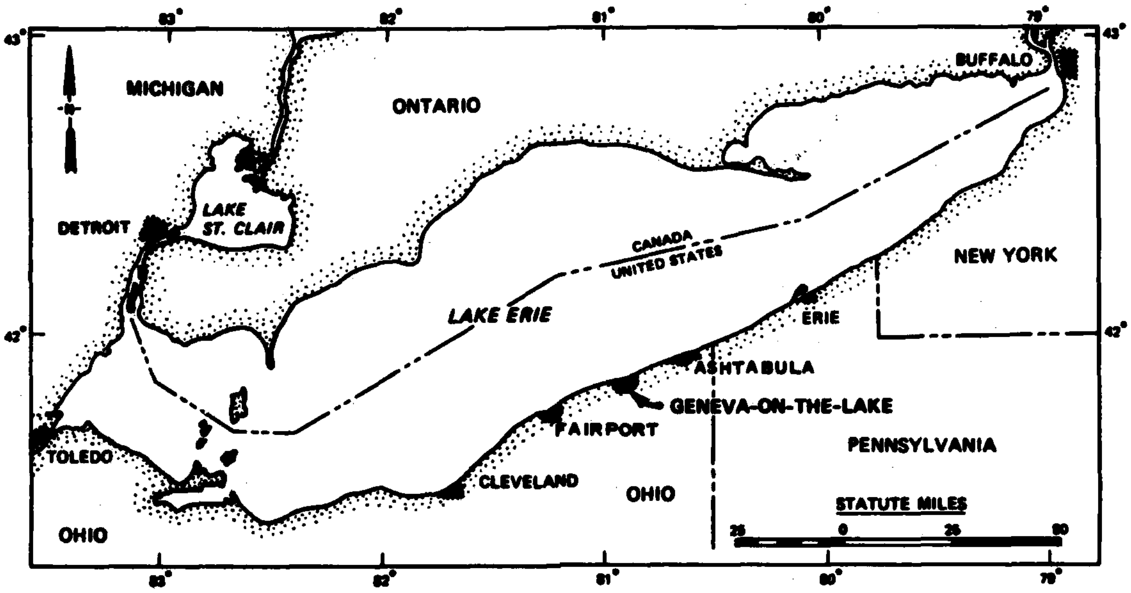

Figure 1. Project location

Figure 2. Aerial view of prototype site

DESIGN FOR WAVE PROTECTION AND PREVENTION OF SHOALING

GENEVA-ON-THE-LAKE SMALL-BOAT HARBOR, OHIO

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Geneva-on-the-Lake is located on the south shore of Lake Erie about 17 miles* east of Fairport Harbor, Ohio, and 12 miles west of Ashtabula Harbor, Ohio (Figure 1). The lake shoreline is generally straight, and the inland area consists of marshes and dunes (Figure 2). The major industry in the area is tourism.

2. Bordering the shoreline for about 1-1/2 miles is the existing and proposed recreational development of Geneva State Park. When completed, the park will encompass approximately 725 acres and will provide facilities for camping, swimming, boating, fishing, picnicking, and hiking.

3. Cowles Creek, which enters Lake Erie near the project site, is about 6 miles long, drains an area of about 23 square miles, and flows westerly and northerly to where it enters the lake at Geneva-on-the-Lake.

Problems and Needs

4. At present, Geneva State Park offers no harbor facilities for boaters desiring to use Lake Erie. The closest facilities are located at Ashtabula and Fairport Harbors, approximately 12 and 17 miles to the east and west of Geneva-on-the-Lake, respectively. These two harbors are currently utilized to full capacity with long waiting lists for permanent dock space. The Ohio Department of Natural Resources has stated

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

that small-boat harbor facilities at Geneva State Park are imperative to promoting optimum use of the park and to satisfying the large-scale demand of prospective and existing small-boat owners in the northeast section of the State of Ohio (U. S. Army Engineer District, Buffalo, 1979).

5. Hazards to small-boat navigation exist due to the absence of a harbor or natural shelter in the 29-mile reach of Lake Erie between Ashtabula and Fairport. The need for a harbor-of-refuge facility becomes more critical each year as more and more recreational craft take to Lake Erie. The Ohio Department of Natural Resources stated that construction of an all-weather facility at Geneva State Park would be a major step in completing Ohio's program to establish a harbor-of-refuge at 15-mile intervals along the Lake Erie shoreline.

6. In general, Geneva-on-the-Lake is an ideal location for a small-boat harbor and harbor-of-refuge because of its strategic location within the boundaries of the State recreational park, its strategic location with respect to existing harbors, its proximity to productive fishing grounds, and appreciable boating demand within the tributary area.

Proposed Improvements

7. The proposed project, as originally authorized, would provide a small-boat harbor and harbor-of-refuge and recreational fishing facilities as an integral part of the State Park at Geneva-on-the-Lake. The plan recommended in House Document No. 91-402 and shown in Figure 3 would consist of the following (U. S. Army Engineer District, Buffalo, 1979):

- a. Breakwaters in Lake Erie aggregating about 1,400 ft in length, with a riprapped spending beach between the entrance channel and the inner end of the west breakwater.
- b. A 1,000-ft-long entrance channel, varying from 180 to 100 ft in width, 8 ft deep for the outer 500 ft and 6 ft deep for the inner 500 ft, extending from the 8-ft contour in the lake into the dock channel.
- c. A dock channel, 100 ft wide, 1,500 ft long, and 6 ft deep, widened to 200 ft at the junction with the entrance channel.
- d. Development of recreational facilities.

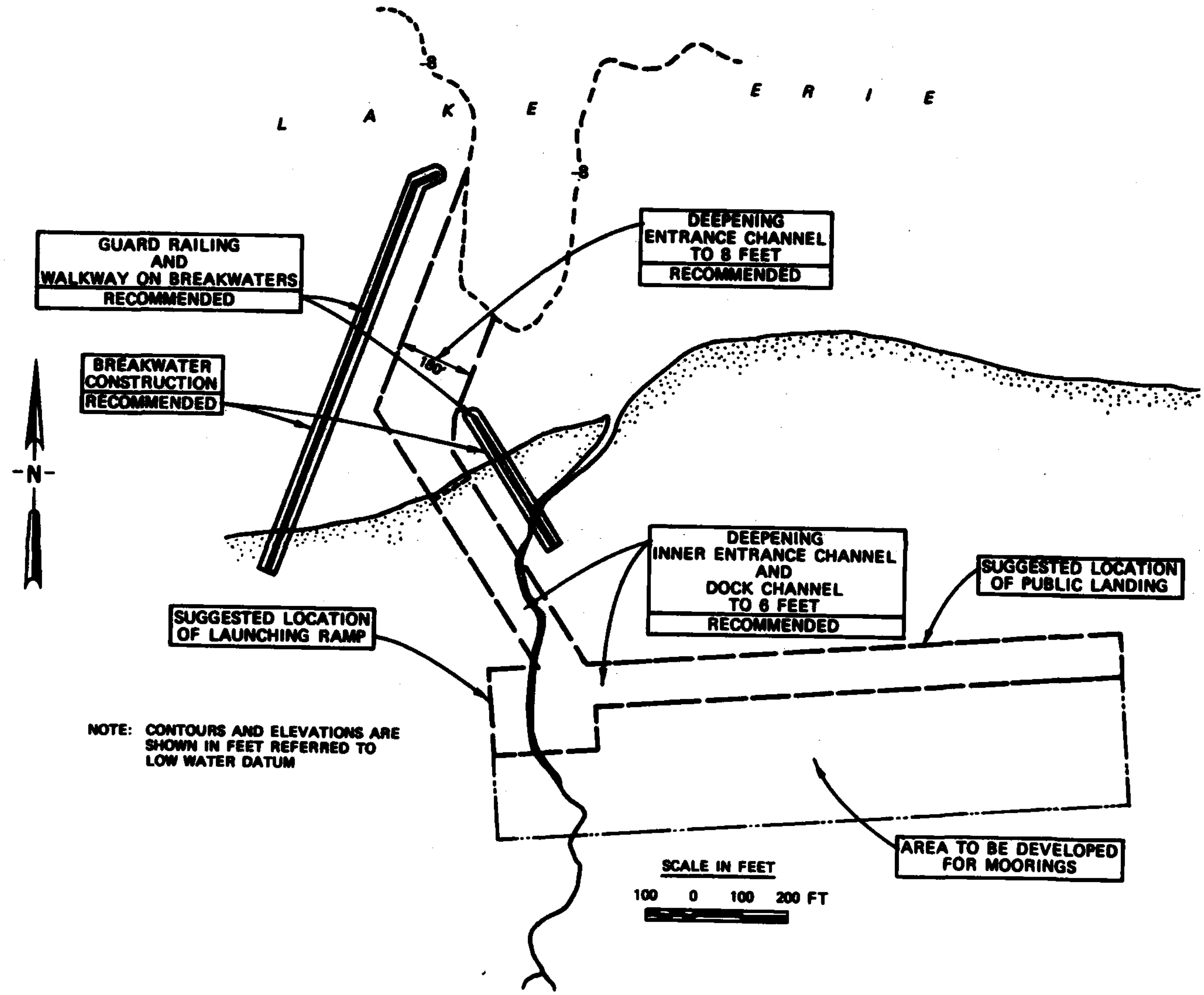

Figure 3. Recommended plan as originally authorized

8. The authorized plan was subsequently modified during the Reformulation Phase I General Design Memorandum study to include the following (Figure 4):

- a. Breakwaters in Lake Erie aggregating about 1,050 ft in length.
- b. An 800-ft-long entrance channel, 100 ft wide and 8 ft deep.
- c. Interior channels totaling about 1,700 ft in length, 100 ft wide and 6 ft deep.
- d. A small-craft refuge area totaling about 0.9 acre in size.
- e. A mitigation plan including a water control structure, creation of about 5 acres of new wetlands, and expansion of an existing island to favor the establishment of waterfowl.
- f. Development of related recreational fishing facilities.

Purpose of the Model Study

9. At the request of the U. S. Army Engineer District, Buffalo (NCB), a hydraulic model investigation was initiated by the U. S. Army Engineer Waterways Experiment Station (WES) to:

- a. Determine the most economical breakwater configuration that would provide adequate wave protection for small craft in the harbor.
- b. Quantify wave heights in the harbor area.
- c. Provide qualitative information on the effects of the breakwaters on the littoral processes.
- d. Develop remedial plans for the alleviation of undesirable conditions as found necessary.

Wave-Height Criteria

10. Completely reliable criteria have not yet been developed for ensuring satisfactory navigation and mooring conditions in small-craft harbors during attack by waves. For this study, however, NCB specified that for an improvement plan to be acceptable, maximum wave heights in

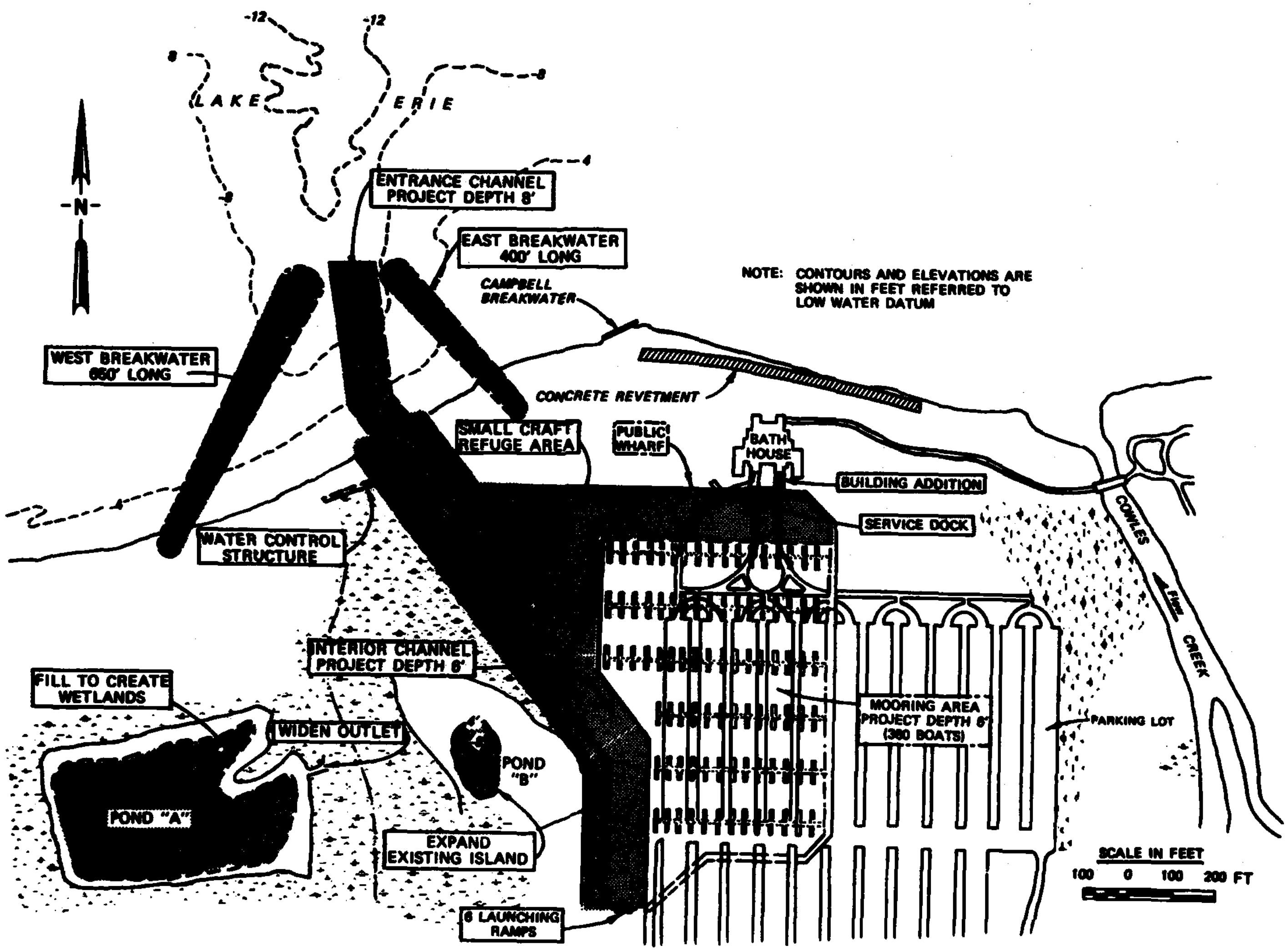

Figure 4. Reformulated plan (as modified during the Reformulation Phase I General Design Memorandum study)

the entrance channel should not exceed 4.0 ft. It was desired that maximum wave heights in the entrance channel not exceed 3.0 ft. In addition, maximum wave heights in the mooring area should not exceed 1.0 ft.

PART II: THE MODEL

Design of Model

11. The Geneva-on-the-Lake model (Figure 5) was constructed to an undistorted linear scale of 1:60, model to prototype. Scale selection was based on such factors as:

- a. Depth of water required in the model to prevent excessive bottom friction.
- b. Absolute size of model waves.
- c. Available shelter dimensions and area required for model construction.
- d. Efficiency of model operation.
- e. Available wave-generating and wave-measuring equipment.
- f. Model construction costs.

A geometrically undistorted model was necessary to ensure accurate reproduction of short-period wave and current patterns. Following selection of the linear scale, the model was designed and operated in accordance with Froude's model law (Stevens et al. 1942). The scale relations used for design and operation of the model were as follows:

Characteristic	Dimension*	Model:Prototype Scale Relation
Length	L**	$L_r = 1:60$
Area	L^2	$A_r = L_r^2 = 1:3,600$
Volume	L^3	$V_r = L_r^3 = 1:216,000$
Time	T	$T_r = L_r^{1/2} = 1:7.75$
Velocity	L/T	$V_r = L_r^{1/2} = 1:7.75$
Roughness (Manning's coefficient, n)	$L^{1/6}$	$n_r = L_r^{1/6} = 1:1.979$
Discharge	L^3/T	$Q_r = L_r^{5/2} = 1:27,885$

* Dimensions are in terms of length and time.

** For convenience, symbols and unusual abbreviations are listed and defined in the Notation (Appendix A).

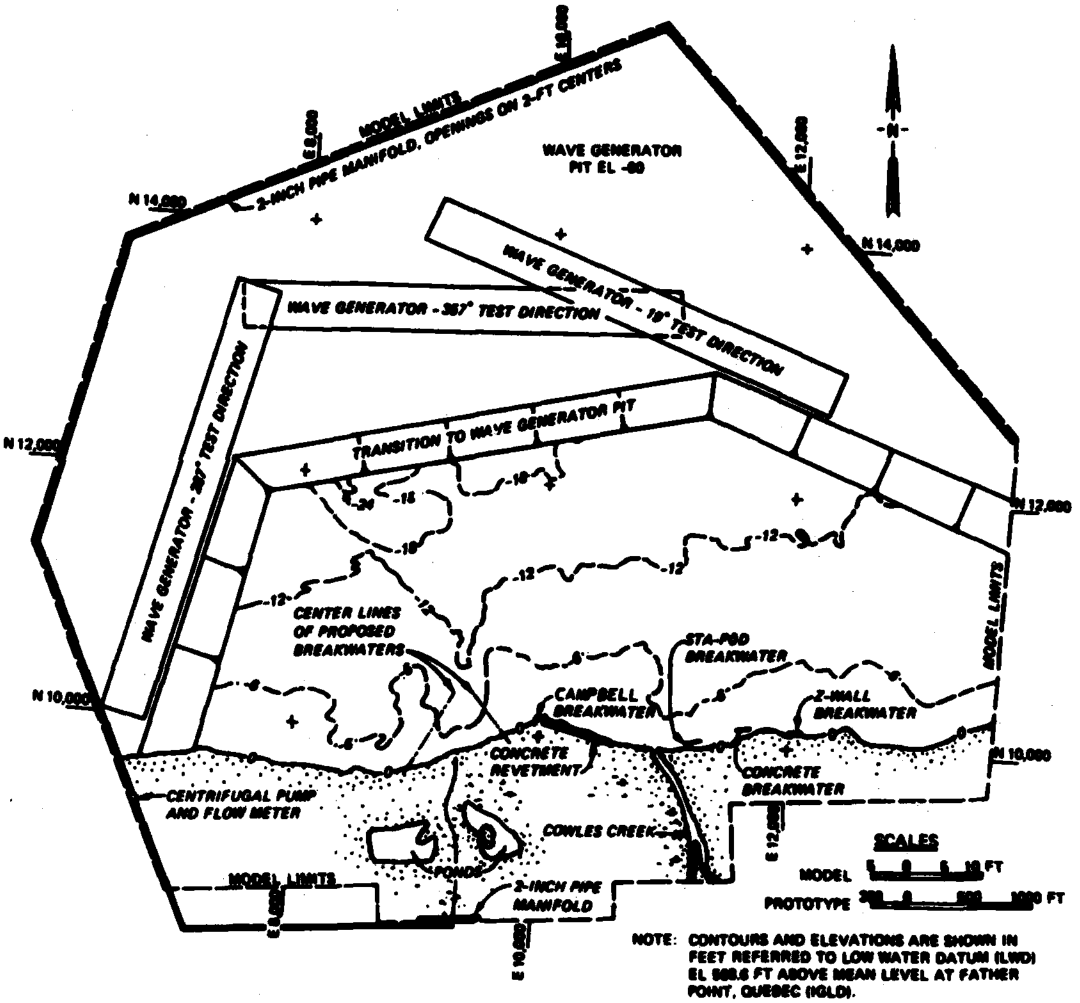

Figure 5. Model layout

12. Proposed improvement plans tested in the model for Geneva-on-the-Lake included the use of rubble-mound breakwaters and revetments. Based on past experience, 1:60-scale model structures should not create sufficient scale effects to warrant geometric distortion of rock sizes in order to ensure proper transmission and reflection of wave energy. Therefore, rock size selection was based on linear scale relations and an assumed specific weight of 165 lb/ft^3 for the prototype rock.

13. The value of Manning's roughness coefficient n used in the design of the wetland area adjacent to the proposed harbor was estimated. An n value of 0.080 was selected and based on previous WES

investigations (Miller and Peterson 1953) and experience, the model area was given a finish that would represent a prototype n value of 0.080.

14. Ideally, a quantitative, three-dimensional, movable-bed model investigation would best determine the effectiveness of various project plans for prevention of shoaling at Geneva-on-the-Lake small-boat harbor. However, this type of model investigation is difficult and expensive to conduct, and each area in which such an investigation is contemplated must be carefully analyzed. The following computations and prototype data are considered essential for such investigations (Chatham, Davidson, Whalin 1973):

- a. A computation of the littoral transport, based on the best available wave statistics.
- b. An analysis of the sand-size distribution over the entire project area (offshore to a point well beyond the breaker zone).
- c. Simultaneous measurements of the following items over a period of erosion and accretion of the shoreline (this measurement period should be judiciously chosen to obtain the maximum probability of both erosion and accretion during as short a time span as possible):
  - (1) Continuous measurements of incident-wave characteristics. Such measurements would mean placing enough redundant sensors to accurately estimate the directional spectrum over the entire project area, and in addition, would mean conducting a rather sophisticated analysis of all these data.
  - (2) Bottom profiling of the entire project area using the shortest time intervals possible.
  - (3) Nearly continuous measurements of both littoral and onshore-offshore transport of sand. These measurements would be especially important over the erosion-accretion period. A wave-forecast service would be essential to this effort to prepare for full operation during the erosion period.

In view of the complexities involved in conducting movable-bed model studies and due to limited funds and time for the Geneva-on-the-Lake project, the model was molded in cement mortar (fixed-bed) at an undistorted scale of 1:60 and a tracer material was obtained to determine qualitatively the degree of shoaling at the harbor entrance for various improvement plans.

The Model and Appurtenances

15. The model reproduced the lower reaches of Cowles Creek; approximately 2,700 and 4,400 ft of shoreline to the east and west of the creek mouth, respectively; and underwater contours in Lake Erie to an offshore depth of -18 ft, with a sloping transition to the wave generator pit elevation of -90 ft. The total area reproduced in the model was approximately 11,390 sq ft, representing about 1.5 square miles in the prototype. A general view of the model, with the reformulated small-boat harbor plan installed, is shown in Figure 6. Vertical control for model construction was based on low water datum (lwd), el 568.6* ft above mean water level at Father Point, Quebec (International Great Lakes Datum, 1955). Horizontal control was referenced to a local prototype grid system.

16. Model waves were generated by a 60-ft-long wave generator with a trapezoidal-shaped, vertical-motion plunger. The vertical movement of the plunger caused a periodic displacement of water incident to this motion. The length of stroke and the frequency of the vertical motion were variable over the range necessary to generate waves with the required characteristics. In addition, the wave generator was mounted on retractable casters which enabled it to be positioned to generate waves from the required directions.

17. A water-circulating system (Figure 5) consisting of 2-in. perforated-pipe water-intake and discharge manifolds, a centrifugal pump, and a flowmeter was used in the model to reproduce steady-state flows through the wetland area adjacent to the proposed harbor.

18. An Automated Data Acquisition and Control System (ADACS), designed and constructed at WES (Figure 7), was used to secure wave-height data at selected locations in the model. Basically, through the use of a minicomputer, ADACS recorded onto magnetic tape the electrical output of parallel-wire, resistance-type sensors that measured the change in

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* All elevations (el) cited herein are in feet referred to low water datum.

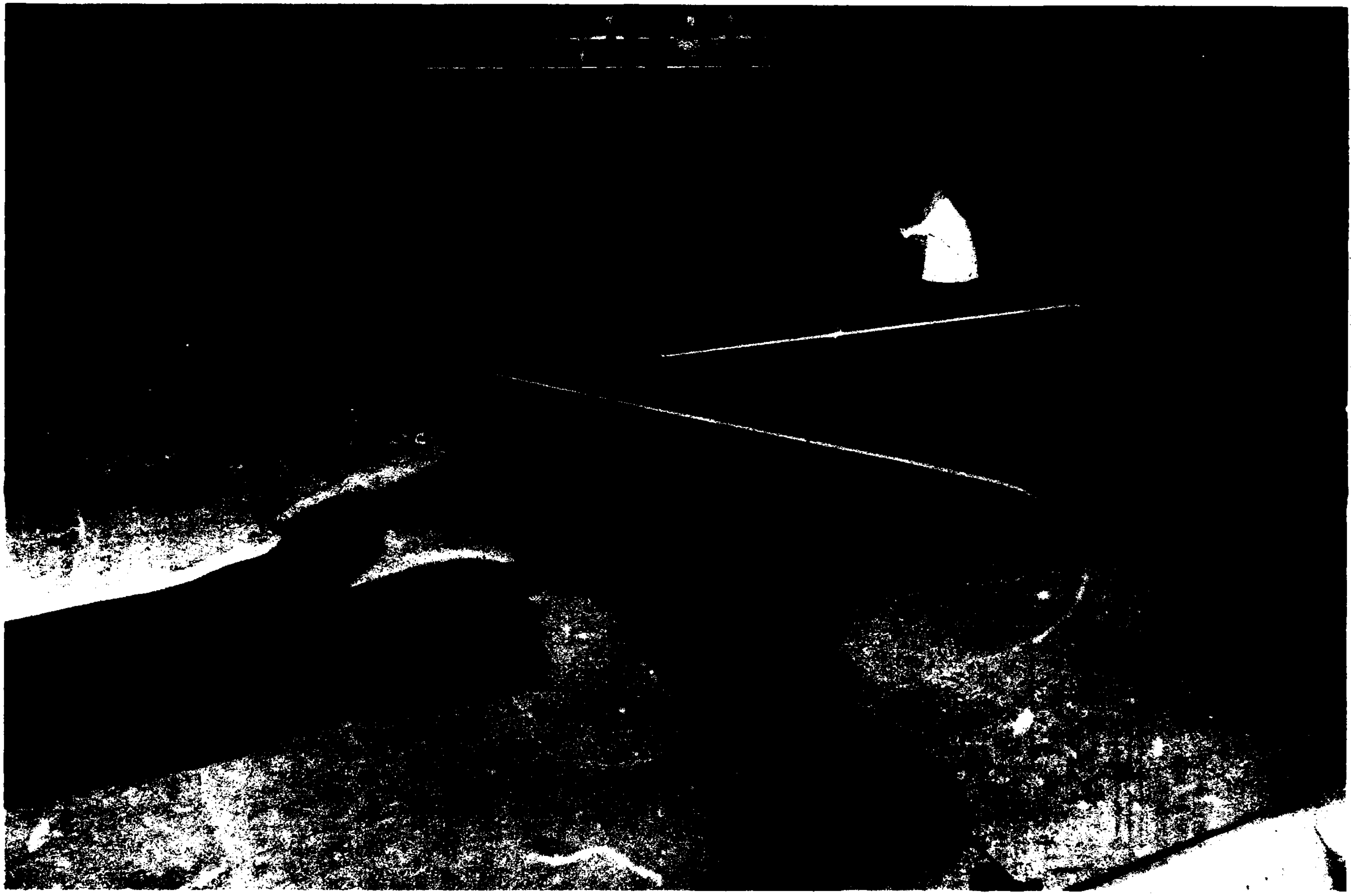

Figure 6. General view of model

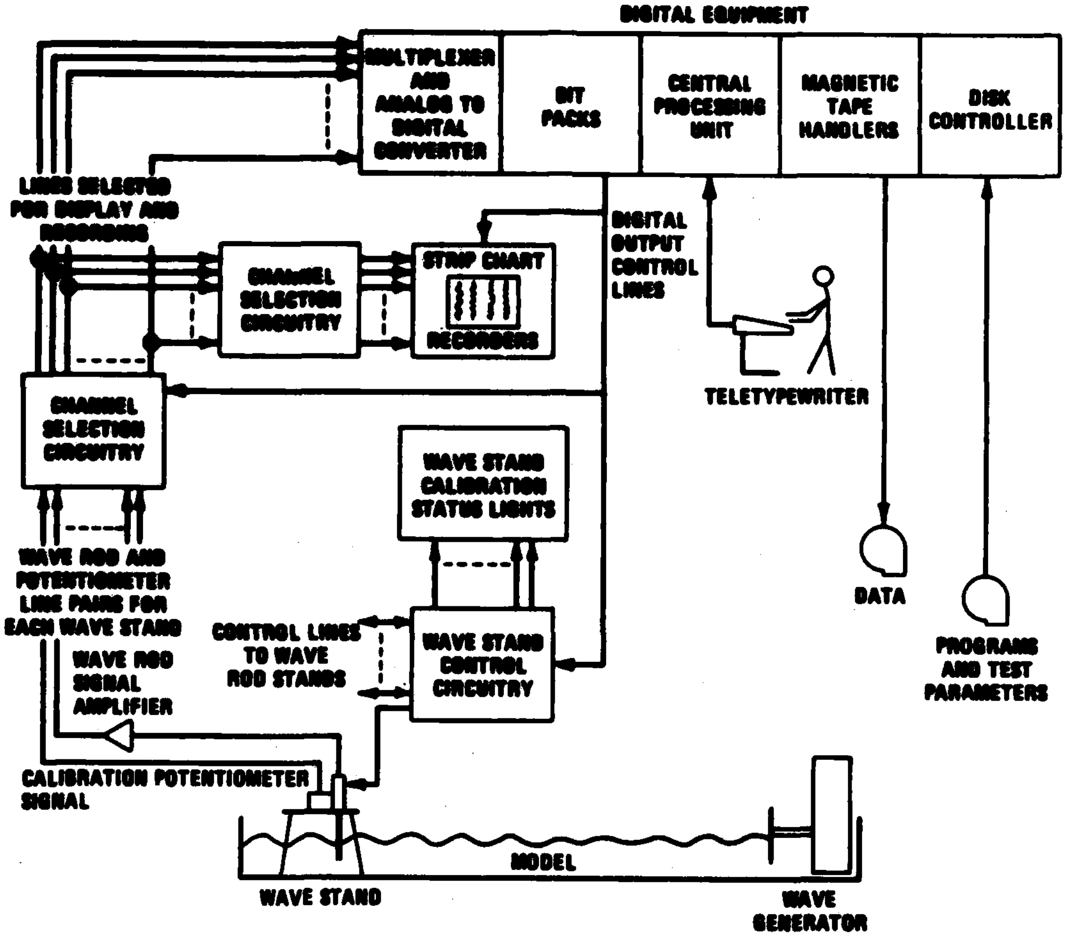

Figure 7. Automated Data Acquisition and Control System (ADACS)

water-surface elevation with respect to time. The magnetic tape output was then analyzed to obtain the required data.

19. Guide vanes were placed along the wave-generator sides to ensure proper formation of the wave train incident to the model contours. In addition, a 2-ft (horizontal) solid layer of fiber wave absorber was placed around the inside perimeter of the model to damp any wave energy that might otherwise be reflected from the model walls.

Selection of Sediment Tracer Material

20. As discussed previously in paragraph 14, a fixed-bed model was constructed and a sediment tracer material selected to determine

qualitatively the degree of shoaling at the harbor entrance for various improvement plans. As in previous WES investigations (Giles and Chatham 1974, Bottin and Chatham 1975), the tracer material was chosen in accordance with the scaling relations of Noda (1972), which indicate a relation or model law among the four basic scale ratios; i.e., the horizontal scale λ , the vertical scale μ , the sediment size ratio η_D , and the relative specific weight ratio $\eta_{\gamma'}$ (Figure 8). These relations were determined experimentally using a wide range of wave conditions and beach materials and are valid mainly for the breaker zone.

21. Noda's scaling relations indicate that movable-bed models with scales in the vicinity of 1:60 (model to prototype) should be distorted (i.e., they should have different horizontal and vertical scales). Since the fixed-bed model of Geneva-on-the-Lake small-boat harbor was undistorted to allow accurate reproduction (similitude of both refraction and diffraction) of short-period wave and current patterns, the following procedure was used to select a tracer material. Using the prototype sand characteristics (median diameter, D_{50} = 0.27 -1.0 mm; specific gravity = 2.65) and assuming the horizontal scale to be in similitude (i.e. 1:60), the median diameter for a given specific gravity of tracer material and the vertical scale were computed. The vertical scale then was assumed to be in similitude and the tracer median diameter and horizontal scale were computed. This resulted in a range of tracer material sizes for given specific gravities that could be used. Of the several types of sediment tracer materials available at WES, previous investigations (Giles and Chatham 1974, Bottin and Chatham 1975) have indicated that crushed coal tracer more nearly represented the movement of prototype sand at the scale used for this study. Therefore, quantities of crushed coal (specific gravity = 1.30, median diameter, D_{50} = 0.8 - 2.9 mm) were selected for use as a tracer material throughout the model investigation.

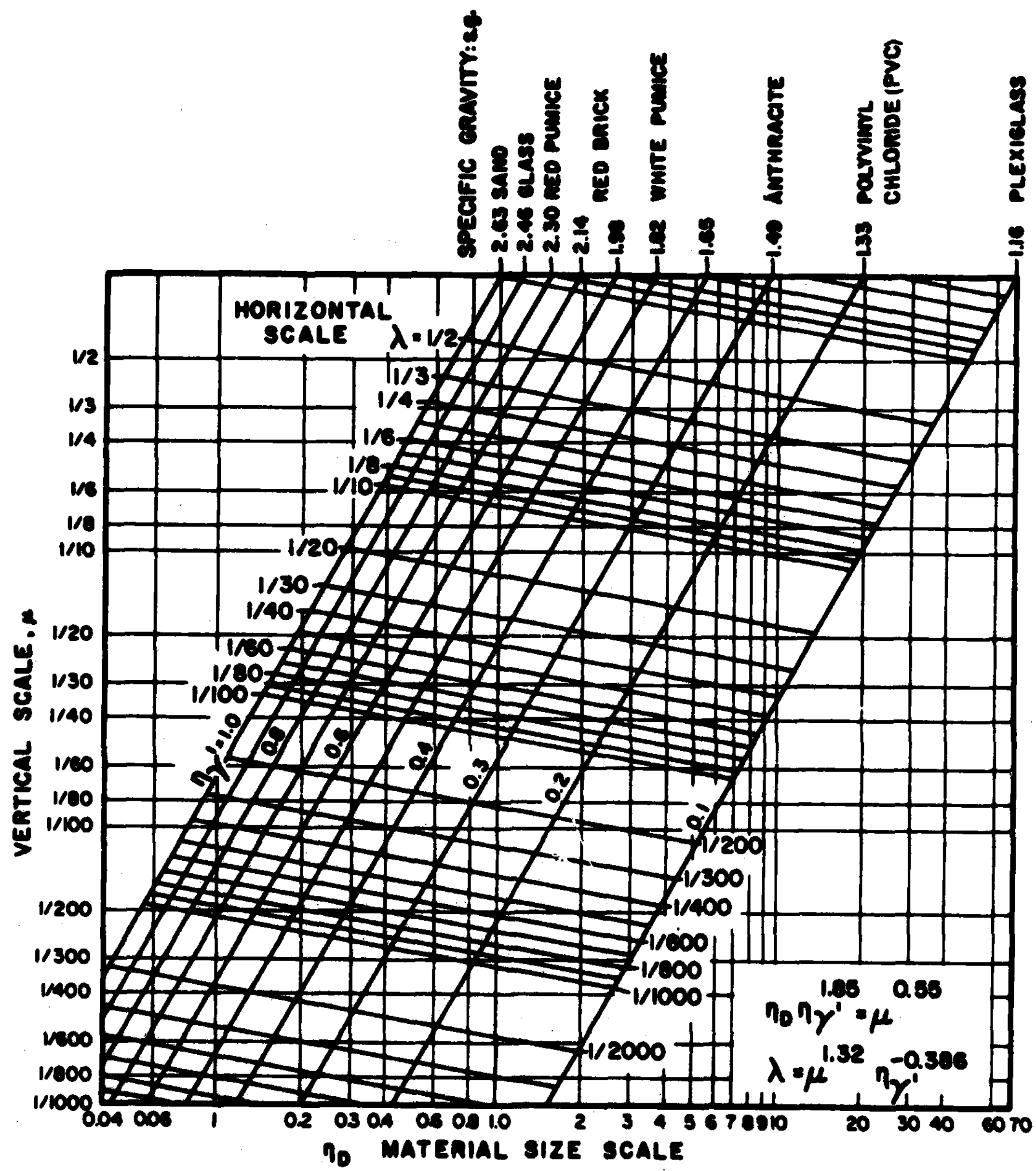

Figure 8. Graphic representation of model law (from Noda 1972)

PART III: TEST CONDITIONS AND PROCEDURES

Selection of Test Conditions

Still-water level

22. Still-water levels (swl's) for harbor wave-action models are selected so that the various wave-induced phenomena which are dependent on water depths are accurately reproduced in the model. These phenomena include the refraction of waves in the harbor area, the overtopping of harbor structures by the waves, the reflection of wave energy from harbor structures, and the transmission of wave energy through porous structures.

23. Water levels on the Great Lakes vary from year to year and from month to month. In many locations, the water level can fluctuate daily or hourly. Since 1860, continuous records of water levels on the Great Lakes have been recorded and maintained. Typical seasonal variations of the lakes consist of high stages in the summer months and low stages in the winter months. For Lake Erie, the higher levels usually occur in June and the lower levels in February. For the period 1860 through 1952, the average level of Lake Erie was +1.8 ft for the entire year and +2.1 ft for the ice-free period (April-November) (Saville 1953). The highest 1-month average level of +4.2 ft occurred in May 1952 and the lowest 1-month average level of -1.1 ft occurred in February 1936. The seasonal variation in the mean monthly level of Lake Erie usually ranges between 1 and 2 ft, with an average variation of 1.6 ft.

24. Seasonal and longer variations in the levels of the Great Lakes are caused by variations in precipitation and other factors that affect the actual quantities of water in the lakes. Wind tides and seiches are relatively short-period fluctuations caused by the tractive force of wind blowing over the water surface and differential barometric pressures, and are superimposed on the longer period variations in the lake level. Large short-period rises in local water level are associated with the most severe storms, which generally occur in the winter when the lake level is usually low; therefore, the probability that a

high lake level and a large wind tide or seiche will occur simultaneously is relatively small.

25. Initially, lake levels of +0.9, +4.0, and +4.4 ft were selected by NCB for use during model testing. The +0.9 ft swl represents mean lake level for the third quarter (July-September) equaled or exceeded 95 percent of the time. The +4.0 ft swl represents a water level with a recurrence interval of 10 years (+3.0 ft) plus a 1.0-ft short-period rise having a 1-year recurrence interval. The +4.4 ft swl has a 20-year recurrence interval (+3.4 ft) plus a 1.0 ft short-period rise with a recurrence interval of 1 year. Testing of additional lake levels of +0.3 and +5.3 ft was requested by NCB during the conduct of model testing. The +0.3 ft swl was used while measuring wave-trough elevations to determine if entrance depths were adequate for entry of small boats during storms and low-water conditions. The +5.3 ft swl was established as the design lake level after the most promising plan was selected and was used to optimize the length of the structures.

Factors influencing selection of test wave characteristics

26. In planning the test program for a model investigation of harbor wave-action problems, it is necessary to select dimensions and directions for the test waves that will allow a realistic test of proposed improvement plans and an accurate evaluation of the elements of the various proposals. Surface-wind waves are generated primarily by the interactions between tangential stresses of wind flowing over water, resonance between the water surface and atmospheric turbulence, and interactions between individual wave components. The height and period of the maximum wave that can be generated by a given storm depend on the wind speed, the length of time that wind of a given speed continues to blow, and the water distance (fetch) over which the wind blows. Selection of test wave conditions entails evaluation of such factors as:

a. The fetch and decay distances (the latter being the distance over which waves travel after leaving the generating area) for various directions from which waves can attack the problem area.

b. The frequency of occurrence and duration of storm winds from the different directions.

c. The alignment, size, and relative geographic position of the navigation entrance to the harbor.

d. The alignments, lengths, and locations of the various reflecting surfaces inside the harbor.

e. The refraction of waves caused by differentials in depth in the area lakeward of the harbor, which may create either a concentration or a diffusion of wave energy at the harbor site.

Wave refraction

27. When wind waves move into water of gradually decreasing depth, transformations take place in all wave characteristics except wave period (to the first order of approximation). The most important transformations with respect to the selection of test wave characteristics are the changes in wave height and direction of travel due to the phenomenon referred to as wave refraction. The change in wave height and direction can be determined by plotting refraction diagrams and calculating refraction coefficients. These diagrams are constructed by plotting the position of wave orthogonals (lines drawn perpendicular to wave crests) from deep water into shallow water. If it is assumed that the waves do not break and that there is no lateral flow of energy along the wave crest, the ratio between the wave height in deep water (H_o) and the wave height at any point in shallow water (H) is inversely proportional to the square root of the ratio of the corresponding orthogonal spacings (b_o and b), or $H/H_o = K_s(b_o/b)^{1/2}$. The quantity $(b_o/b)^{1/2}$ is the refraction coefficient K_r ; K_s is the shoaling coefficient. Thus, the refraction coefficient multiplied by the shoaling coefficient gives a conversion factor for transfer to deepwater wave heights to shallow-water values. The shoaling coefficient, a function of wavelength and water depth, can be obtained from U. S. Army Coastal Engineering Research Center, CE (1977).

28. For this study, wave-refraction diagrams were prepared by NCB and used by WES personnel to determine wave heights and refracted wave directions at the wave generator location for representative wave periods from the critical directions of deepwater wave approach. Refraction

and shoaling coefficients are summarized in Table 1. The wave-height adjustment factor, obtained by multiplying K_r times K_s, can be applied to any deepwater wave height to obtain the corresponding shallow-water value. Based on the refracted directions obtained at the wave generator locations, the deepwater and corresponding shallow-water directions selected for use during model testing were as follows:

Deepwater Direction, Azimuth, deg	Corresponding Shallow-Water Test Direction, Azimuth, deg
270	287
360	357
30	19

Prototype wave data and selection of test waves

29. Measured prototype data on which a comprehensive statistical analysis of wave conditions could be based were unavailable for the Geneva-on-the-Lake project area. However, statistical deepwater wave hindcast data representative of this area were obtained from Resio and Vincent (1976a) shoreline grid point 14. The numerical wave and wind models used to produce this data are described in Resio and Vincent (1976b, 1977a, 1977b, and 1978). Resio and Vincent (1976a) cover deepwater waves approaching from three angular sectors at the site (Figure 9). Table 2 gives the significant wave heights for all approach angles and seasons combined for recurrence intervals of 5, 10, 20, 50, and 100 years. Table 3 shows significant wave period by angle class and wave height. The characteristics of waves used during model testing were representative of wave conditions occurring during navigation season (spring, summer, and fall). Model test waves were selected from Tables 2 and 3 and converted to shallow-water values by application of refraction and shoaling coefficients as shown in the following tabulation:

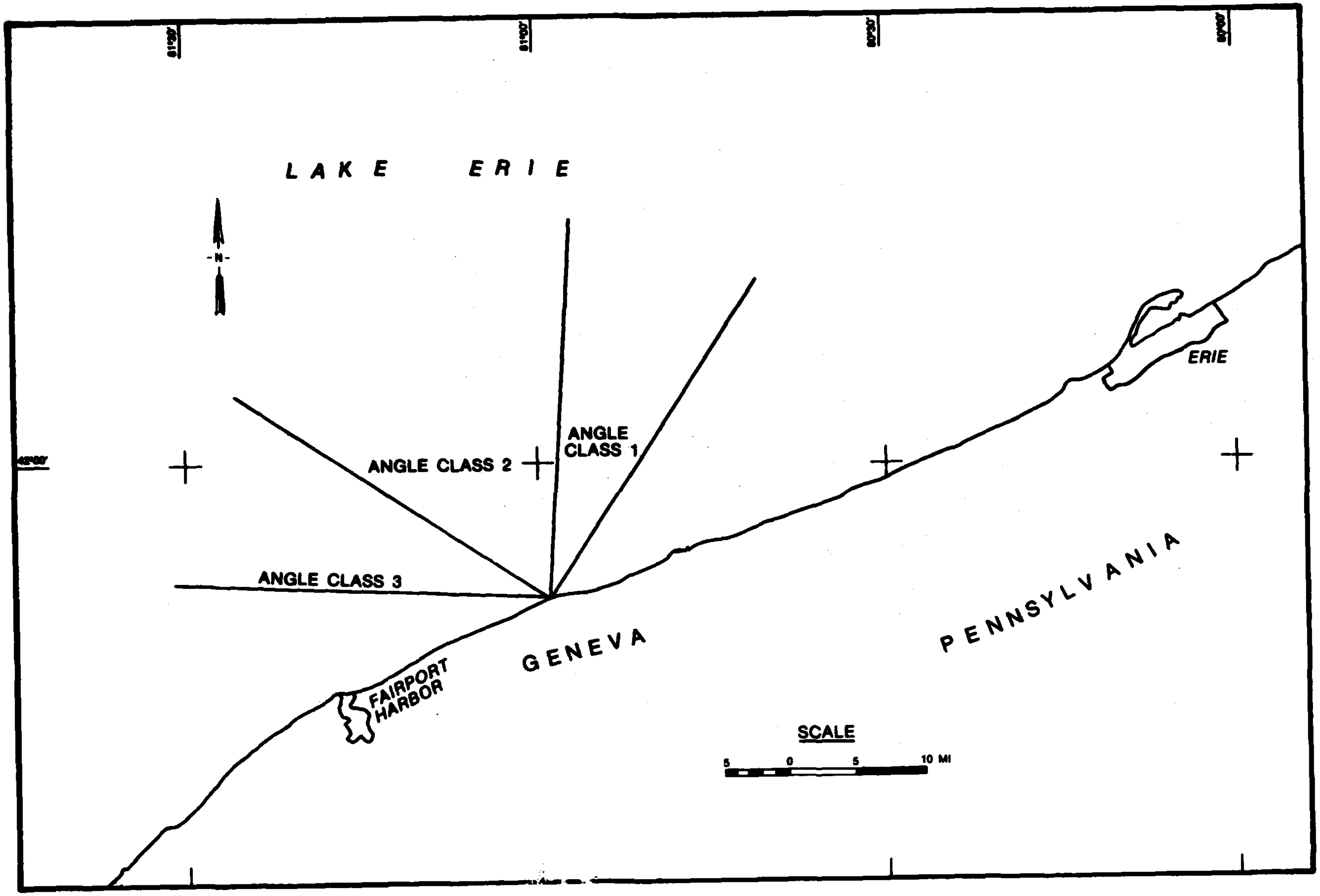

Figure 9. Wave hindcast angle classes

Deepwater Azimuth deg	Shallow-Water Azimuth deg	Wave Period sec	Deepwater Wave Height ft	Shallow-Water Wave Height ft	Recurrence Interval (Season)* year
270	287	6.6	6.2	5.6	5 (SU)
		7.4	8.2	7.5	20 (SU)
		8.8**	11.5**	10.4**	10 (F)**
		9.0	12.1	10.9	20 (F)
360	357	5.8	4.9	4.6	5 (SU)
		6.5	7.5	7.1	20 (SP)
		7.6**	11.5**	10.4**	10 (F)**
		7.8	12.1	10.9	20 (F)
30	19	5.5	4.6	4.4	20 (SP)
		6.2	6.6	6.3	20 (SU)
		7.1	9.8	9.1	20 (F)

* SU - summer, SP - spring, and F - fall seasons.
** Tested with +4.4 ft swl only--others tested with +0.3, +0.9, +4.0, and/or +5.3 ft swl.

Wetland discharges

30. The proposed reformulated small-boat harbor is to be constructed adjacent to a wetland area. Portions of construction entail a water control structure and concrete spillway where the wetland area empties into Lake Erie. Discharges from the wetland area of 65 and 800 cfs were selected for use in model testing for the optimum improvement plans. The 800-cfs discharge represents a 100-year occurrence due to runoff resulting from storm activity and the 65-cfs discharge represents a peak instantaneous flow due to lowering the water level in the wetlands at the water control structure.

Analysis of Model Data

31. The relative merits of the various plans tested were evaluated by:

a. Comparison of wave heights at selected locations in the harbor and entrance channel.

b. Comparison of wave-induced current patterns and magnitudes.

c. Comparison of sediment tracer material movement and subsequent deposits.

d. Visual observations and photographs.

In the wave-height data analysis, the average height of the highest one-third of the waves recorded at each gage location was computed. All wave heights then were adjusted to compensate for excessive model wave-height attenuation due to viscous bottom friction by application of Keulegan's equation (Keulegan 1950). From this equation, reduction of wave heights in the model (relative to the prototype) can be calculated as a function of water depth, width of wave front, wave period, water viscosity, and distance of wave travel. Wave-induced current magnitudes were obtained by timing the progress of an injected dye tracer relative to a thin graduated scale placed on the model floor.

PART IV: TESTS AND RESULTS

The Tests

Existing conditions

32. Prior to testing of the various improvement plans, tests were conducted for existing conditions (Plate 1). Current patterns and magnitudes, wave pattern photographs, and sediment tracer patterns were obtained for representative waves from the three test directions.

Base Test

33. Comprehensive tests were conducted with the proposed harbor but for prebreakwater conditions (Base Test) prior to testing of the various improvement plans. Wave-height data were obtained at locations in the harbor (Plate 2) for the test waves listed in paragraph 29. Wave pattern photographs and tracer patterns also were secured for representative test waves from the three selected test directions.

Improvement plans

34. Wave-height tests were conducted for 29 test plan variations of the basic reformulated harbor design. These variations consisted of changes in the lengths, alignments, crest elevations, and/or cross sections of the breakwater structures. Wave pattern photographs were obtained for all the test plans, while current patterns and magnitudes and tracer patterns were obtained for the most promising improvement plan. Brief descriptions of the improvement plans are presented in the following subparagraphs; dimensional details are presented in Plates 3-10. Typical breakwater and revetment sections are shown in Plate 11 for Plans 1-7E.

a. Plan 1 (Plate 3), the basic reformulated plan, consisted of a 650-ft-long west breakwater with a +5.9 ft crest elevation and a 400-ft-long east breakwater with a crest elevation of +6.6 ft. The lakeward slope of these structures was 1V on 2H, while the slope on the channel side was 1V on 1.5H. Also included was a 100-ft-wide, 8-ft-deep entrance channel, extending from the -8 ft contour in Lake Erie to the inner channels where the depth decreased to -6 ft. The depth of the mooring area (which encompasses greater than 7 acres) was also -6 ft.

Revetments extended along the entire western side of the harbor on the levee adjacent to the wetlands and also on the eastern side of the entrance for about 200 ft.

b. Plan 2 (Plate 4) entailed the elements of Plan 1 except that the crest elevations of the west and east breakwaters were raised to +8 ft and small spurs were installed at the revetted entrance. These spurs extended lakeward about 25 ft, and were installed with crest elevations of +6 ft.

c. Plan 2A (Plate 4) involved the elements of Plan 2 with a 50-ft extension of the east breakwater installed parallel to the entrance channel.

d. Plan 2B (Plate 4) entailed the elements of Plan 2 with a 100-ft extension of the east breakwater installed parallel to the entrance channel.

e. Plan 2C (Plate 4) consisted of the elements of Plan 2 with 100-ft extensions of the east and west breakwaters installed parallel to the entrance channel.

f. Plan 2D (Plate 4) involved the elements of Plan 2 with a 150-ft extension of the east breakwater and a 100-ft extension of the west breakwater installed parallel to the entrance channel.

g. Plan 2E (Plate 5) entailed the elements of Plan 2 with 125-ft extensions of the east and west breakwaters installed parallel to the entrance channel.

h. Plan 2F (Plate 5) involved the elements of Plan 2 with 150-ft extensions of the east and west breakwaters installed parallel to the entrance channel.

i. Plan 2G (Plate 5) consisted of the elements of Plan 2 with 175-ft extensions of the east and west breakwaters installed parallel to the entrance channel.

j. Plan 2H (Plate 5) entailed the elements of Plan 2 with 200-ft extensions of the east and west breakwaters installed parallel to the entrance channel.

k. Plan 2I (Plate 5) consisted of the elements of Plan 2F but the crest elevations of the east and west breakwaters were reduced to +7 ft.

l. Plan 2J (Plate 5) entailed the elements of Plan 2F but the east and west breakwater crest elevations were increased to +9 ft.

m. Plan 3 (Plate 6) involved the elements of Plan 2 with 75-ft extensions of the east and west breakwaters installed parallel to the entrance channel. The slopes on the channel sides of these extensions were 1V on 2H.

n. Plan 3A (Plate 6) consisted of the elements of Plan 3 but the east and west breakwater extensions were 125 ft long.

o. Plan 3B (Plate 6) entailed the elements of Plan 3 but the east and west breakwater extensions were 150 ft long.

p. Plan 4 (Plate 7) consisted of a 780-ft-long west breakwater and a 540-ft-long east breakwater (both with crest elevations of +8 ft). The west and east breakwaters were reoriented lakeward of the original alignment approximately 5 and 10 deg, respectively.

q. Plan 5 (Plate 8) consisted of a 750-ft-long west breakwater and a 500-ft-long east breakwater. Two 100-ft-long spurs were installed between the breakwaters with a 200-ft-wide gap between them. The spurs originated approximately 200 ft shoreward of the heads of the east and west breakwaters. The crest elevations of these structures were +8 ft.

r. Plan 5A (Plate 8) entailed the elements of Plan 5 but the west and east breakwater spurs were moved 50 ft shoreward. The west spur was increased to 150 ft in length and the east spur to 115 ft to maintain the 200-ft gap between the structures.

s. Plan 6 (Plate 9) consisted of a 500-ft-long west breakwater and a 430-ft-long east breakwater (both installed with crest elevations of +8 ft). The lakeward portion of the entrance channel was shifted slightly to the east of the original alignment.

t. Plan 6A (Plate 9) involved the elements of Plan 6 with a 100-ft extension of the west breakwater installed parallel to the entrance channel.

u. Plan 6B (Plate 9) entailed the elements of Plan 6 with a 200-ft extension of the west breakwater installed parallel to the entrance channel.

v. Plan 6C (Plate 9) consisted of the elements of Plan 6 with a 200-ft extension of the west breakwater and a 100-ft extension of the east breakwater installed parallel to the entrance channel.

w. Plan 6D (Plate 9) entailed the elements of Plan 6 with 200-ft extensions of both the west and east breakwaters installed parallel to the entrance channel.

x. Plan 7 (Plate 10) consisted of a 900-ft-long west breakwater (crest el +8 ft) and a 400-ft-long east breakwater (crest el +8 ft). The entrance channel was oriented to the east of the original alignment.

y. Plan 7A (Plate 10) involved the elements of Plan 7 with a

100-ft extension of the east breakwater installed parallel to the entrance channel.

z. Plan 7B (Plate 10) entailed the elements of Plan 7 with a 200-ft extension of the east breakwater installed parallel to the entrance channel.

aa. Plan 7C (Plate 10) consisted of the elements of Plan 7 with a 200-ft extension of the east breakwater and a 100-ft extension of the west breakwater installed parallel to the entrance channel.

bb. Plan 7D (Plate 10) entailed the elements of Plan 7 with 100-ft extensions of both the east and west breakwaters installed parallel to the entrance channel.

cc. Plan 7E (Plate 10) involved the elements of Plan 7 with a 100-ft extension of the west breakwater installed parallel to the entrance channel.

Wave-height tests

35. Wave-height tests for the various improvement plans were conducted using test waves from one or more of the directions listed in paragraph 29. Tests involving certain proposed improvement plans were limited to the most critical direction of wave approach (i.e., 357 deg). The most promising plans of improvement were tested comprehensively for waves from all three test directions (i.e., 287, 357, and 19 deg). Wave gage locations for each improvement plan are shown in Plates 3-10.

Wave-induced current pattern and magnitude tests

36. Wave-induced current patterns and magnitudes were determined at selected locations by timing the progress of a dye tracer relative to a known distance on the model floor. These tests were conducted for the most promising improvement plan (Plan 2H) for representative test waves from all three test directions.

Sediment tracer tests

37. Sediment tracer tests were limited to only the most promising improvement plan (Plan 2H) using representative test waves from all three test directions. Tracer material was introduced into the model west of the west breakwater and east of the east breakwater to represent sediment from those shorelines, respectively. Some tests also were conducted to determine deposition of sediment (inside the breakwaters) along

the shoreline adjacent to the control structure under various wave attack conditions.

Wetland discharge tests

38. Discharges of 65 and 800 cfs were reproduced through the wetlands for the most promising improvement plan (Plan 2H). Most of these flow tests were conducted in conjunction with wave-height tests for Plan 2H to determine the effect of these discharges on wave heights in the entrance. Some tests were conducted to determine velocities in the wetland area when the water level was artificially lowered by means of the water control structure.

Model boat tests

39. A small-scale remote-controlled model cabin cruiser was used with Plan 2H installed in the model to aid in determining effects of boat wakes in the harbor. Although the available model vessel was not to scale (i.e. 1:60), it was felt that it could be used to qualitatively determine the existence (if any) and/or location of standing waves in the harbor as a result of boat wakes reflecting off the vertical harbor walls. Numerous photographs, visual observations, and videotape footage were used to document test results.

Videotape

40. Videotape footage of the Geneva-on-the-Lake harbor model was secured with Plan 2H installed and forwarded to the U. S. Army Engineer Division, North Central (NCD), for use in briefings, public meetings, etc. Included in this footage were the following:

a. Various test waves approaching the harbor entrance from 357 and 287 deg.

b. Tracer tests for waves from 357 and 287 deg.

c. Views of the model cabin cruiser entering and leaving the harbor from various locations.

Test Results

41. In evaluating test results, the relative merits of various plans were based on an analysis of measured wave heights, wave-induced

current patterns and magnitudes, and/or the movement of tracer material and subsequent deposits. Model wave heights (significant wave height or $H_{1/3}$) were tabulated to show measured values at selected locations. Wave-induced current patterns and magnitudes were superimposed on wave pattern photographs for the corresponding plan and wave condition tested. The general movement of tracer material and subsequent deposits were shown in photographs. Arrows were superimposed onto these photographs to depict sediment movement patterns.

Existing conditions

42. Wave-induced current patterns and magnitudes obtained for existing conditions for representative test waves from all three directions are shown in Photos 1-19. Maximum velocities obtained at various locations were as follows:

Location	Maximum Velocity fps	swl	Test Wave	Direction deg
Area west of proposed entrance	6.0	+4.4	7.6-sec, 10.4-ft	357
Area between proposed breakwaters	5.9	+4.0	6.5-sec, 7.1-ft	357
Area east of proposed entrance	5.9	+4.0	9.0-sec, 10.9-ft	287
	5.9	+4.4	8.8-sec, 10.4-ft	287

In general, current movement was from west to east for test waves from 287 deg and from east to west from 19 deg. For test waves from 357 deg, current patterns divided at a point east of the proposed entrance with some current movement to the west and some to the east. Typical wave patterns for existing conditions also are shown in Photos 1-19.

43. The general movement of tracer material and subsequent deposits for existing conditions for representative test waves from all three directions are shown in Photos 20-33. Tracer material moved from west to east for test waves from 287 deg and from east to west for test waves from 19 deg. For test waves from 357 deg, tracer material divided at a point east of the proposed entrance with some material moving to the west and some to the east.

Base Test

44. Wave-height measurements obtained for the Base Test are presented in Table 4. Maximum wave heights were 8.1 ft in the entrance channel (gage 2) and 1.4 ft in the mooring area (gage 13) for 7.6-sec, 10.4-ft test waves from 357 deg with the +4.4 ft swl.

45. Wave and tracer patterns secured for representative waves from the three test directions are shown in Photos 34-44. The general movement of tracer material was from west to east for test waves from 287 deg, and tracer material deposited in the entrance channel. For test waves from 357 deg, tracer material divided at a point east of the proposed entrance with some material moving to the west into the entrance channel and some moving along the shoreline to the east. Test waves from 19 deg resulted in tracer movement from east to west with material depositing in the entrance channel.

Improvement plans

46. Wave-height tests conducted for Plan 1, the basic reformulated plan, for test waves from 287, 357, and 19 deg are presented in Table 5. Maximum wave heights were 7.2 ft in the entrance channel (gage 2) for 7.8-sec, 10.9-ft test waves from 357 deg with the +4.0 ft swl and 1.6 ft in the mooring area (gage 14) for 6.5-sec, 7.1-ft test waves from 357 deg with the +4.0 ft swl. The desired wave-height criteria of 3.0 ft in the entrance channel (gage 2) and 1.0 ft in the mooring area (gages 10-15) were exceeded for several of the test waves. Significant breakwater overtopping was observed for various test waves from all test directions. Typical wave patterns for Plan 1 are shown in Photos 45-54.

47. Wave-height measurements obtained for Plans 2-2H for representative test waves from 357 deg with the +0.9, +4.0, and/or +4.4 ft swl are presented in Table 6. For the +4.0 ft swl, maximum wave heights in the entrance (gage 2) were 4.9, 4.2, 4.0, 3.4, 3.3, 3.2, and 2.5 ft for Plans 2-2F, respectively. For the +4.4 ft swl, maximum wave heights in the entrance were 4.6, 4.8, 4.0, 3.4, 3.2, and 2.7 ft for Plans 2, 2C, and 2E-2H, respectively. Wave heights in the mooring area were

1.0 ft or less for all the Plan 2 series test plans. Wave patterns for Plans 2-2H are shown in Photos 55-63.

48. Results of wave-height tests obtained for Plans 3-3B for representative test waves from 357 deg using the +4.0 and +4.4 ft swl are presented in Table 7. For the +4.0 ft swl, maximum wave heights in the entrance (gage 2) were 4.8, 4.0, and 2.9 ft for Plans 3-3B, respectively. For the +4.4 ft swl, maximum wave heights were 3.6 and 3.0 ft in the entrance for Plans 3A and 3B, respectively. Wave heights in the mooring area (gages 10-15) were 0.6 ft or less for all Plan 3 series test plans. Wave patterns secured for Plans 3-3B are shown in Photos 64-66.

49. Wave-height data obtained for Plan 4 for representative test waves from 357 deg are presented in Table 8. Maximum wave heights obtained in the entrance (gage 2) for the +4.0 and +4.4 ft swl were 4.5 and 5.5 ft, respectively. Maximum wave heights of 0.7 ft occurred in the mooring area (gages 10-15) for both the +4.0 and +4.4 ft swl. A typical wave pattern of Plan 4 is shown in Photo 67.

50. Results of wave-height tests with Plans 5 and 5A installed are presented in Table 9 for representative test waves from 357 deg. For the +4.0 ft swl, maximum wave heights in the entrance (gage 2) were 3.8 ft for both Plans 5 and 5A. For the +4.4 ft swl, maximum wave heights in the entrance were 4.4 and 3.9 ft for Plans 5 and 5A, respectively. The maximum wave height obtained in the mooring area (gages 10-15) was 0.7 ft, which occurred for Plan 5 with a +4.0 ft swl. Typical wave patterns for Plans 5 and 5A are shown in Photos 68 and 69.

51. Wave-height measurements obtained for Plans 6-6D for representative test waves from 357 deg are presented in Table 10. For the +4.0 ft swl, maximum wave heights in the entrance (gage 2) were 4.8, 3.5, 2.9, and 2.7 ft for Plans 6-6C, respectively. For the +4.4 ft swl, maximum wave heights in the entrance were 5.6, 4.3, 3.5, 2.9, and 2.3 ft for Plans 6-6D, respectively. Wave heights in the mooring area (gages 10-15) were 0.6 ft or less for all the Plan 6 series test plans. Wave patterns for Plans 6-6C are shown in Photos 70-73.

52. Results of wave-height tests for Plans 7-7E are shown in Table 11 for representative test waves from 357 deg. For the +4.0 ft

swl, maximum wave heights in the entrance (gage 2) were 4.0, 3.4, 3.4, 2.4, 2.8, and 3.7 ft for Plans 7-7E, respectively. For the +4.4 ft swl, maximum wave heights were 4.1, 3.5, 3.6, 1.8, 2.3, and 3.5 ft in the entrance for Plans 7-7E, respectively. Wave heights in the mooring area (gages 10-15) were 0.4 ft or less for all the Plan 7 series test plans. Typical wave patterns for Plans 7-7E are shown in Photos 74-79.

53. An evaluation of test results obtained to this point indicated that Plan 2F appeared to be the optimum with respect to wave protection, orientation of navigation entrance, and cost of construction. Therefore, Plan 2F was reinstalled in the model and subjected to comprehensive wave-height tests. Wave heights obtained for test waves from 287, 357, and 19 deg are presented in Table 12. Maximum wave heights were 3.4 ft in the entrance channel (gage 2) for 7.6-sec, 10.9-ft waves from 357 deg with the +4.4 ft swl and 0.8 ft in the mooring area (gage 12) for 6.5-sec, 7.1-ft waves from 357 deg with the +0.9 ft swl.

54. Wave-height data were obtained for Plan 2F seaward of the navigation entrance (gages 1A and 1B) for test waves from 287, 357, and 19 deg using a +0.3 ft swl. Wave-trough elevations were recorded to determine if entrance depths were adequate for entry of small boats during storms. Results of these tests are shown in Table 13. A trough elevation of -3.0 ft was obtained at gage 1B for 6.5-sec, 7.1-ft test waves from 357 deg.

55. Results of wave-height tests conducted for Plan 2I for test waves from all three directions are presented in Table 14. Maximum wave heights were 3.9 ft in the entrance channel (gage 2) for 7.6-sec, 10.4-ft waves from 357 deg with the +4.4 ft swl and 0.6 ft in the mooring area (gages 10-15) for several of the test waves.

56. At this stage in the model investigation, NCB requested additional tests using a revised design swl of +5.3 ft. With Plan 2F installed, wave-height data were obtained along the shoreline east of the harbor entrance (gages 16-23) using the +0.9, +4.0, +4.4, and +5.3 ft swl to provide wave information in an area proposed for a future beach restoration study. Results of these tests are presented in Table 15. Maximum wave heights obtained were 9.9 ft for 6.2-sec, 6.3-ft and 7.1-sec,

9.1-ft test waves from 19 deg with the +5.3 ft swl.

57. Wave-height tests were conducted for Plans 2F, 2H, and 2J for representative test waves from 357 deg using the +4.4 and +5.3 ft swl. Results of these tests are shown in Table 16. Maximum wave heights obtained were 3.9, 3.3, and 4.0 ft in the entrance (gage 2) for Plans 2F, 2H, and 2J, respectively.

58. Comprehensive wave-height measurements were secured for Plan 2H using the +0.9, +4.0, +4.4, and +5.3 ft swl and are presented in Table 17. Maximum wave heights were 3.3 ft in the entrance channel (gage 2) for 7.8-sec, 10.9-ft waves from 357 deg with the +5.3 ft swl and 0.6 ft in the mooring area (gages 10-15) for 6.6-sec, 5.6-ft waves from 287 deg and 7.8-sec, 10.9-ft waves from 357 deg with the +5.3 ft swl.

59. Wave heights obtained with Plan 2H installed for test waves from 357 deg with 65- and 800-cfs discharges from the wetland area adjacent to the proposed small-boat harbor are presented in Table 18. A comparison of these tests with those for Plan 2H with no flow reveals that in general, the flows had little effect on wave heights. In some cases, wave heights increased slightly at gages 1 and 1A for the 800-cfs discharge; however, wave heights in the inner entrance (gage 2) remained about the same.

60. During the conduct of wave-height tests for various improvement plans, visual observations were made of wave runup on the shoreline adjacent to the east and west breakwaters. It was determined that berms (el +12) tying the shoreward ends of the breakwaters to higher ground were required to prevent waves from flanking the breakwaters.

61. Wave-induced current patterns and magnitudes were obtained for Plan 2H for representative test waves from all three directions and are shown in Photos 80-97. Maximum velocities obtained at various locations were as follows:

Location	Maximum Velocity fps	swl	Test Wave	Direction deg
Shoreline west of breakwaters	3.2	+5.3	7.1-sec, 9.1-ft	19
Area west of west breakwater	5.2	+4.0	7.8-sec, 10.9-ft	357
Area between east and west breakwaters	2.3	+0.9	7.8-sec, 10.9-ft	357
Area seaward of entrance	6.5	+0.9	9.0-sec, 10.9-ft	287
	6.5	+4.0	9.0-sec, 10.9-ft	287
Area east of east breakwater	3.9	+5.3	7.8-sec, 10.9-ft	357
Shoreline east of breakwaters	4.3	+0.9	7.8-sec, 10.9-ft	357

In general, current movement was from west to east for test waves from 287 deg and from east to west for test waves from 19 deg. For test waves from 357 deg, current patterns separated at a point east of the east breakwater with some movement around the structures to the west and some to the east. Typical wave patterns for Plan 2H also are shown in Photos 80-97.

62. The general movement of tracer material and subsequent deposits obtained for Plan 2H for representative test waves from all three directions are shown in Photos 98-115. For test waves from 287 deg, the tracer moved from west to east. That material on the west shoreline accumulated against the west breakwater, and material on the east shoreline moved easterly. For test waves from 357 deg, tracer material on the west shoreline generally moved toward the west and tracer on the east shoreline divided at a point east of the east breakwater with some moving to the west against the breakwater and some moving along the shoreline to the east. For test waves from 19 deg, tracer material moved from east to west. Material on the east shoreline accumulated against the east breakwater, and material on the west shoreline migrated westerly. Tracer material did not move into the small-boat harbor entrance for any of the test waves from either direction.

63. Tracer material was placed along the shoreline between the

west revetment spur (adjacent to the entrance) and the west breakwater for Plan 2H and subjected to representative test waves from 287, 357, and 19 deg to determine the stability of the shoreline in this area. Through visual observations, it was noted that test waves from 287 deg had little effect on this material; however, test waves from 357 and 19 deg (357 deg to a greater extent) tended to erode the shoreline west of the spur, moving sediment westerly. This indicates that the shoreline can be expected to reorient itself in the vicinity of the control structure due to diffracted wave energy (through the breakwaters) reaching the shoreline.

64. The water level in the wetland area (adjacent to the proposed harbor) was artificially lowered by means of the water control structure. Velocities of 0.1 fps were observed in the wetlands with the control structure open and are shown in Photo 116.

65. The model cabin cruiser was navigated in and out of the harbor and visual observations, photographs, and videotape footage were obtained. Views of the model boat entering and leaving the harbor from various locations are shown in Photos 117-129. These photographs were obtained at 3-sec intervals and depict the path of the vessel entering and/or leaving the harbor. The wake created by the model vessel dissipates relatively quickly, and no significant standing waves were observed in the harbor.

Discussion of test results

66. Test results for existing conditions revealed current and sediment movement to the east for test waves from 287 deg and to the west for test waves from 19 deg. For test waves from 357 deg (waves approaching normal to the shoreline), tests indicated current and sediment movement would divide at a point east of the proposed entrance with some moving to the west and some to the east.

67. Test results obtained for Base Test (the proposed harbor without breakwaters) revealed rough and turbulent wave conditions in the vicinity of the proposed harbor with wave heights in excess of 8 ft well into the entrance channel (gage 2). Tracer tests indicated that with no breakwaters sediment would deposit in the entrance channel.

68. Results of wave-height tests for Plan 1 revealed that the established wave-height criteria in the entrance channel and mooring area of the harbor were exceeded for several test waves due to significant overtopping of the breakwaters.

69. An evaluation of wave-height tests conducted for Plans 2-2H, 3-3B, 4, 5-5A, 6-6D, and 7-7E revealed that Plans 2D-2H, 3A and 3B, 5A, 6B-6D, and 7A-7E resulted in wave heights within the established criteria (wave heights not to exceed 4.0 ft in the inner entrance and 1.0 ft in the mooring area) for initial test conditions (maximum swl of +4.4 ft). Considering wave protection, orientation of the navigation entrance, and construction costs, however, Plan 2F appeared to be optimal.

70. A comparison of wave heights for Plans 2F, 2H, and 2J with the +5.3 ft swl reveals that each plan meets the established wave-height criteria; however, the 3.3-ft wave heights in the entrance for Plan 2H were more desirable than the 3.9- and 4.0-ft wave heights of Plans 2F and 2J, respectively.

71. An evaluation of wave-height tests conducted for Plan 2H with various discharges from the wetland area indicated that these flows had little effect on wave heights. Wave heights increased slightly at the lakeward gages, in some cases, for the maximum 800-cfs discharge, but wave heights in the inner entrance remained about the same.

72. Tracer tests conducted for Plan 2H revealed that sediment will not move into the small-boat harbor entrance for any wave conditions from the directions tested. Tracer did accumulate against the west breakwater for test waves from 287 deg and against the east breakwater for test waves from 357 and 19 deg. (Note: At a meeting with NCB personnel on 28 October 1981, it was concluded that sand bypassing will probably be required to return the sediment that accumulates against the breakwaters back into the littoral system.)

73. Tests conducted with tracer material placed along the shoreline between the west revetment spur and west breakwater indicated that erosion may occur in the area of the control structure, and the shoreline may have a tendency to reorient in this area due to diffracted wave energy (through the breakwaters) reaching the shoreline. Therefore, a

revetment may be necessary to prevent erosion and undermining of the structure. Another alternative would be to construct the control structure after the breakwaters are installed and the shoreline in the area stabilizes.

74. The stability of the Plan 2H breakwaters (where they angled from the arrowhead portions to the 200-ft parallel extensions) became a point of concern during the conduct of the model investigation. While this model was not intended to look at stability (i.e. the model scale would need to be about 1:24 to have negligible scale effects), visual observations of model tests revealed no tendency toward stability problems. Additionally, based on past experience, stone on the inner (acute) portion of the angle (lakeward side) should be very stable. However, stone on the outer (obtuse) portion of the angle (channel side) could be unstable due to storm waves propagating through the entrance if inadequate stone sizes are used. To minimize or alleviate this condition, it is suggested that the stone sizes used on the parallel extensions be extended around the angle toward the shoreline (i.e., stone sizes should not be reduced at the angle).

75. Test results obtained with the model cabin cruiser indicated no significant problem in the harbor with regard to boat-generated standing waves. The initial wake from the boat did reflect off the vertical walls but tended to dissipate quickly.

76. Provided the absorbers in the entrance and along the levee on the west side of the harbor remain in place, minor geometric changes in the inner harbor (due to possible design changes relating to inner harbor features) should have no adverse impact on the wave climate in the mooring area as it exists for the present layout and further model testing is not required.

PART V: CONCLUSIONS

77. Based on the results of the hydraulic model investigation reported herein, it was concluded that:

- a. For existing conditions, sediments and currents along the shoreline in the vicinity of the proposed harbor may move in either direction (east or west) depending on the incident wave direction.
- b. With the proposed harbor installed with no breakwaters (Base Test), rough and turbulent wave conditions existed in the harbor entrance during periods of storm-wave attack.
- c. With the proposed harbor installed with no breakwaters (Base Test), sediment deposited in the entrance channel.
- d. For the originally proposed improvement plan (Plan 1), significant overtopping of the breakwaters occurred resulting in excessive wave heights in the entrance and mooring areas.
- e. Of the improvement plans tested under initial test conditions (maximum swl of +4.4 ft), Plan 2F (150-ft extensions of the +8 ft elevation east and west breakwaters) appeared to be optimal with respect to wave protection, orientation of the navigation entrance, and construction costs (although several test plans met the established wave-height criteria).
- f. Of the improvement plans tested with the revised maximum swl of +5.3 ft, Plan 2H (200-ft extensions of the +8 ft elevation east and west breakwaters) appeared to be the most desirable with respect to wave protection.
- g. Discharges from the wetland area (adjacent to the proposed small-boat harbor) had little effect on wave heights in the harbor entrance for Plan 2H.
- h. Sediment accumulated against the outside of the breakwaters of Plan 2H, but did not enter the harbor entrance for any wave conditions tested.
- i. To prevent erosion and/or undermining of the water control structure, a revetment should be installed, or the structure should be constructed after the breakwaters are installed and the shoreline in the area stabilizes.
- j. To prevent waves from flanking the breakwaters, berms (el +12) tying the shoreward ends of the breakwaters to higher ground were required.

k. Waves in the harbor generated by the model boat (boat wake) dissipated quickly and caused no standing wave problems in the harbor.

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Table 1

Summary of Refraction and Shoaling Analysis for Geneva-on-the-Lake, Ohio

Deepwater Direction deg	Wave Period sec	Shallow-Water* Azimuth deg	Refraction* Coefficient	Shoaling** Coefficient	Wave-Height Adjustment Factor
270	8.3	286.3	0.98	0.93	0.91
	9.0	286.8	0.98	0.92	0.90
	9.4	287.7	0.98	0.92	0.90
330	6.5	332.4	0.98	0.98	0.96
	7.8	332.7	0.97	0.95	0.92
	8.1	333.2	0.97	0.94	0.91
360	6.5	358.0	0.96	0.98	0.94
	7.8	357.3	0.95	0.95	0.90
	8.1	357.0	0.95	0.94	0.89
30	6.2	19.7	0.97	0.99	0.96
	7.2	18.5	0.97	0.96	0.93

* At model contours.

** At 90-ft depth (model pit elevation).

Table 2

Wave Heights for All Approach Angles and Seasons

Recurrence Interval, year	Wave Height, ft Angle Class 1	Angle Class 2	Angle Class 3
	Winter		
5	6.6	10.5	10.8
10	8.2	12.1	12.1
20	9.8	13.4	13.1
50	12.1	15.4	14.4
100	13.8	16.7	15.4
	Spring		
5	3.6	4.3	6.9
10	3.6	5.9	7.9
20	4.6	7.5	9.2
50	5.9	10.2	10.5
100	6.9	11.8	11.8
	Summer		
5	4.3	4.9	6.2
10	5.2	5.9	7.2
20	6.6	6.6	8.2
50	9.2	7.2	9.2
100	11.2	7.5	9.8
	Fall		
5	8.2	10.5	10.8
10	9.2	11.5	11.5
20	9.8	12.1	12.1
50	10.5	13.4	13.1
100	11.5	14.4	13.8

Table 3

Significant Period, sec, by Angle Class and Wave Height

Wave Height ft	Significant Period, sec		
	Angle Class 1	Angle Class 2	Angle Class 3
1	2.3	2.3	2.5
2	3.6	3.6	3.8
3	4.5	4.5	4.8
4	5.2	5.2	5.5
5	5.8	5.8	6.1
6	6.1	6.1	6.5
7	6.3	6.4	6.9
8	6.6	6.6	7.3
9	6.9	6.9	7.7
10	7.2	7.2	8.2
11	7.4	7.5	8.6
12	7.7	7.8	9.0
13	8.0	8.0	9.4
14	8.2	8.3	9.8
15	8.5	8.6	10.2
16	8.8	8.9	10.6
17	9.0	9.2	11.0
18	9.3	9.4	11.4
19	9.6	9.7	11.8
20	9.9	10.0	12.3
21	10.1	10.3	12.7
22	10.4	10.6	13.1
23	10.7	10.8	13.5
24	10.9	11.1	13.9
25	11.2	11.4	14.3

TABLE 4

WAVE HEIGHTS FOR BASE TEST

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
SWL = +0.9 FT										
287	6.6	5.6	5.8	4.1	1.9	1.0	0.4	0.4	0.6	0.3
	7.4	7.5	5.3	3.5	2.1	0.7	0.6	0.5	0.4	0.3
	9.0	10.9	3.8	4.7	1.5	0.7	0.5	0.4	0.3	0.6
357	5.8	4.6	2.8	1.8	1.5	0.6	0.4	0.2	0.3	0.1
	6.5	7.1	6.8	3.2	1.9	0.7	0.4	0.3	0.6	0.3
	7.8	10.9	4.9	4.1	1.8	0.8	0.5	0.4	0.4	0.6
19	5.5	4.4	3.3	2.5	1.4	0.7	0.4	0.4	0.6	0.4
	6.2	6.3	4.3	2.7	1.3	0.6	0.3	0.2	0.3	0.2
	7.1	9.1	4.3	2.7	1.0	0.3	0.2	0.1	0.2	0.3
SWL = +4.0 FT										
287	6.6	5.6	12.9	4.6	3.5	1.1	0.7	0.6	0.7	0.6
	7.4	7.5	8.3	4.8	3.0	1.3	1.4	1.0	0.7	0.9
	9.0	10.9	6.4	4.7	2.5	1.1	0.8	0.7	0.6	0.7
357	5.8	4.6	3.9	1.3	0.8	0.3	0.2	0.1	0.1	0.1
	6.5	7.1	9.3	5.5	3.3	1.3	0.7	0.8	0.7	0.7
	7.8	10.9	8.6	3.8	3.0	0.7	1.1	1.1	0.8	0.7
19	5.5	4.4	1.5	2.9	2.1	1.2	0.7	0.8	0.8	0.5
	6.2	6.3	5.8	4.0	2.9	1.1	0.9	0.9	0.9	0.6
	7.1	9.1	5.4	3.7	2.6	0.8	0.6	0.5	0.6	0.5
SWL = +4.4 FT										
287	8.8	10.4	7.9	5.2	3.4	2.0	0.9	0.6	0.7	1.1
357	7.6	10.4	8.5	8.1	5.1	1.4	1.9	1.4	1.2	1.4

(CONTINUED)

TABLE 4 (CONCLUDED)

TEST WAVE DIRECTION DEG	TEST WAVE PERIOD SEC	TEST WAVE HEIGHT FT	WAVE HEIGHT, FT GAGE 9	GAGE 10	GAGE 11	GAGE 12	GAGE 13	GAGE 14	GAGE 15
					SWL = +0.9 FT				
287	6.6	5.6	0.2	0.3	0.4	0.6	0.4	0.3	0.5
	7.4	7.5	0.3	0.3	0.4	0.4	0.2	0.5	0.5
	9.0	10.9	0.4	0.4	0.6	0.6	0.4	0.4	0.6
357	5.8	4.6	0.2	0.2	0.4	0.5	0.3	0.4	0.4
	6.5	7.1	0.2	0.4	0.6	0.7	0.4	0.4	0.4
	7.8	10.9	0.4	0.3	0.6	0.7	0.3	0.4	0.5
19	5.5	4.4	0.5	0.2	0.5	0.6	0.2	0.3	0.3
	6.2	6.3	0.2	0.3	0.3	0.5	0.2	0.3	0.3
	7.1	9.1	0.3	0.2	0.2	0.3	0.2	0.3	0.3
					SWL = +4.0 FT				
287	6.6	5.6	0.7	0.5	0.9	1.1	0.4	1.2	1.2
	7.4	7.5	0.5	0.7	1.1	1.1	0.7	0.8	1.0
	9.0	10.9	0.4	0.8	0.7	0.7	0.7	0.8	0.9
357	5.8	4.6	0.1	<0.1	0.2	0.4	<0.1	0.2	0.3
	6.5	7.1	0.6	1.1	0.8	1.0	0.7	1.3	1.1
	7.8	10.9	0.5	0.7	0.7	0.5	0.7	0.5	0.7
19	5.5	4.4	1.1	0.5	1.1	1.1	0.6	0.9	0.9
	6.2	6.3	0.5	0.7	0.8	1.2	0.5	1.0	0.8
	7.1	9.1	0.4	0.5	0.6	0.8	0.4	0.9	0.7
					SWL = +4.4 FT				
287	8.8	10.4	0.6	1.1	1.2	1.2	0.8	0.9	1.3
357	7.6	10.4	0.7	1.3	1.2	0.9	1.4	0.8	0.9

TABLE 5

WAVE HEIGHTS FOR PLAN 1

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
					SWL = +0.9 FT					
287	6.6	5.6	4.7	2.2	1.0	0.4	0.2	0.2	0.3	0.1
	7.4	7.5	4.5	2.4	0.6	0.3	0.1	0.1	0.2	0.1
	9.0	10.9	5.8	2.1	1.3	0.5	0.3	0.3	0.3	0.4
357	5.8	4.6	3.4	1.9	1.0	0.3	0.4	0.2	0.3	0.1
	6.5	7.1	5.8	3.5	1.6	0.6	0.3	0.4	0.5	0.2
	7.8	10.9	5.4	2.9	1.1	0.4	0.3	0.3	0.3	0.2
19	5.5	4.4	3.9	1.9	1.1	0.5	0.4	0.3	0.5	0.2
	6.2	6.3	4.7	2.7	1.4	0.5	0.3	0.3	0.4	0.2
	7.1	9.1	6.2	2.8	1.4	0.4	0.2	0.3	0.3	0.2
					SWL = +4.0 FT					
287	6.6	5.6	7.8	2.7	1.6	0.8	0.3	0.3	0.2	0.4
	7.4	7.5	6.4	3.4	1.7	0.6	0.4	0.4	0.3	0.4
	9.0	10.9	5.7	2.6	1.2	0.7	0.5	0.4	0.5	0.4
357	5.8	4.6	3.9	2.6	1.5	0.7	0.7	0.5	0.9	0.4
	6.5	7.1	8.8	5.9	3.0	1.1	0.7	0.9	0.9	0.7
	7.8	10.9	9.4	7.2	3.5	0.9	1.3	1.1	1.2	0.7
19	5.5	4.4	2.1	1.8	1.0	0.6	0.3	0.3	0.3	0.4
	6.2	6.3	5.6	3.6	2.0	0.8	0.6	0.5	0.6	0.4
	7.1	9.1	5.4	3.5	1.8	0.5	0.4	0.3	0.4	0.3
					SWL = +4.4 FT					
287	8.8	10.4	6.8	3.2	1.8	0.9	0.4	0.4	0.3	0.6
357	7.6	10.4	9.5	5.6	2.9	0.9	0.9	0.8	0.6	0.5

(CONTINUED)

TABLE 5 (CONCLUDED)

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
				SWL = +0.9 FT					
287	6.6	5.6	0.2	0.1	0.4	0.4	0.2	0.2	0.2
	7.4	7.5	0.2	0.1	0.2	0.3	<0.1	0.3	0.3
	9.0	10.9	0.3	0.2	0.4	0.4	0.2	0.3	0.4
357	5.8	4.6	0.3	0.2	0.3	0.4	0.2	0.4	0.4
	6.5	7.1	0.3	0.3	0.5	0.6	0.4	0.5	0.4
	7.8	10.9	0.2	0.2	0.3	0.4	0.2	0.4	0.4
19	5.5	4.4	0.3	0.2	0.4	0.5	0.2	0.3	0.3
	6.2	6.3	0.3	0.2	0.3	0.5	0.2	0.5	0.4
	7.1	9.1	0.2	0.2	0.3	0.4	0.2	0.4	0.3
				SWL = +4.0 FT					
287	6.6	5.6	0.3	0.3	0.4	0.5	0.2	0.5	0.7
	7.4	7.5	0.3	0.3	0.4	0.4	0.3	0.4	0.5
	9.0	10.9	0.4	0.4	0.5	0.6	0.4	0.6	0.5
357	5.8	4.6	0.4	0.5	0.5	1.1	0.5	0.5	0.8
	6.5	7.1	0.7	0.7	0.8	1.1	0.4	1.6	1.2
	7.8	10.9	0.6	0.7	0.7	0.7	1.1	0.9	0.8
19	5.5	4.4	0.5	0.2	0.6	0.6	0.3	0.2	0.3
	6.2	6.3	0.5	0.5	0.7	1.1	0.3	1.1	0.8
	7.1	9.1	0.4	0.4	0.5	0.6	0.2	0.8	0.5
				SWL = +4.4 FT					
287	8.8	10.4	0.4	0.4	0.7	0.7	0.4	0.5	0.6
357	7.6	10.4	0.5	0.6	0.6	0.7	0.7	0.7	0.7

TABLE 6

WAVE HEIGHTS FOR PLANS 2-2H FOR TEST WAVES

FROM 357 DEG DIRECTION

Plan	Test Wave Period, sec	Test Wave Height, ft	Wave Height, ft: Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
			SWL = +0.9 FT							
2	5.8	4.6	3.7	1.6	0.7	0.3	0.2	0.2	0.3	0.2
	6.5	7.1	3.6	2.4	0.9	0.3	0.1	0.2	0.2	0.3
	7.8	10.9	4.8	2.9	1.1	0.3	0.1	0.1	0.1	0.2
			SWL = +4.0 FT							
	5.8	4.6	3.4	2.4	1.3	0.7	0.4	0.4	0.3	0.5
	6.5	7.1	5.9	3.2	1.7	0.8	0.4	0.5	0.4	0.4
	7.8	10.9	8.7	4.9	2.0	0.7	0.5	0.3	0.3	0.6
2A		10.9	5.6	4.2	1.3	0.6	0.4	0.4	0.4	0.6
2B		10.9	5.2	4.0	1.4	0.6	0.3	0.3	0.2	0.5
2C		10.9	4.7	3.4	1.3	0.5	0.3	0.3	0.2	0.5
2D		10.9	4.6	3.3	1.2	0.5	0.3	0.2	0.2	0.4
2E		10.9	4.1	3.2	1.4	0.6	0.3	0.2	0.2	0.4
2F		10.9	4.1	2.5	0.8	0.3	0.2	0.2	0.2	0.4
			SWL = +4.4 FT							
2	7.6	10.4	7.7	4.6	1.8	0.4	0.4	0.3	0.2	0.4
2C		10.4	7.2	4.8	2.0	0.7	0.6	0.4	0.4	0.5
2E		10.4	6.9	4.0	1.5	0.5	0.4	0.3	0.3	0.5
2F		10.4	5.2	3.4	1.2	0.4	0.3	0.3	0.2	0.3
2G		10.4	4.7	3.2	1.2	0.3	0.3	0.2	0.2	0.4
2H		10.4	4.5	2.7	1.1	0.2	0.3	0.2	0.2	0.3

(CONTINUED)

TABLE 6 (CONCLUDED)

Plan	Test Wave Period sec	Test Wave Height ft	Wave Height, ft Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
				SWL = +0.9 FT					
2	5.8	4.6	0.3	0.1	0.2	0.3	0.2	0.2	0.2
	6.5	7.1	0.1	0.2	0.3	0.3	0.2	0.2	0.2
	7.8	10.9	0.2	0.1	0.2	0.3	0.1	0.3	0.3
				SWL = +4.0 FT					
	5.8	4.6	0.5	0.3	0.8	1.0	0.3	0.2	0.5
	6.5	7.1	0.4	0.6	0.4	0.7	0.3	1.0	0.6
	7.8	10.9	0.5	0.4	0.5	0.5	0.3	0.4	0.4
2A		10.9	0.3	0.4	0.5	0.5	0.3	0.4	0.4
2B		10.9	0.3	0.3	0.4	0.4	0.2	0.4	0.4
2C		10.9	0.2	0.2	0.3	0.3	0.2	0.2	0.3
2D		10.9	0.3	0.3	0.4	0.4	0.1	0.3	0.3
2E		10.9	0.3	0.3	0.5	0.5	0.2	0.4	0.4
2F		10.9	0.2	0.2	0.3	0.2	0.2	0.2	0.3
				SWL = +4.4 FT					
2	7.6	10.4	0.2	0.2	0.3	0.3	0.2	0.2	0.2
2C		10.4	0.4	0.4	0.6	0.5	0.3	0.3	0.4
2E		10.4	0.3	0.3	0.4	0.4	0.3	0.2	0.2
2F		10.4	0.2	0.2	0.2	0.3	0.2	0.3	0.3
2G		10.4	0.2	0.2	0.2	0.3	0.1	0.2	0.2
2H		10.4	0.2	0.2	0.3	0.2	0.1	0.2	0.2

TABLE 7

WAVE HEIGHTS FOR PLANS 3-3B FOR TEST WAVES

FROM 357 DEG DIRECTION

PLAN	TEST WAVE PERIOD SEC	TEST WAVE HEIGHT FT	WAVE HEIGHT, FT GAGE 1	GAGE 2	GAGE 3	GAGE 4	GAGE 5	GAGE 6	GAGE 7	GAGE 8
					SWL = +4.0 FT					
3	7.8	10.9	6.2	4.8	1.7	0.7	0.4	0.3	0.2	0.7
3A		10.9	6.3	4.0	1.5	0.5	0.3	0.3	0.2	0.5
3B		10.9	4.5	2.9	1.1	0.5	0.3	0.2	0.2	0.4
					SWL = +4.4 FT					
3A	7.6	10.4	5.8	3.6	1.3	0.2	0.3	0.2	0.2	0.3
3B		10.4	6.1	3.0	1.0	0.3	0.3	0.2	0.2	0.4

(CONTINUED)

TABLE 7 (CONCLUDED)

	Test Wave		Wave Height, ft						
Plan	Period sec	Height ft	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
				SWL = +4.0 FT					
3	7.8	10.9	0.4	0.5	0.6	0.5	0.2	0.5	0.5
3A		10.9	0.3	0.4	0.5	0.4	0.1	0.3	0.4
3B		10.9	0.3	0.2	0.4	0.4	0.2	0.2	0.3
				SWL = +4.4 FT					
3A	7.6	10.4	0.2	0.2	0.3	0.2	0.2	0.2	0.2
3B		10.4	0.2	0.2	0.3	0.3	0.2	0.2	0.2

TABLE 8

WAVE HEIGHTS FOR PLAN 4 FOR TEST WAVES

FROM 357 DEG DIRECTION

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 1B	Gage 1A	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7
					SWL = +0.9 FT						
357	5.8	4.6	3.5	3.6	3.3	1.9	1.0	0.5	0.3	0.2	0.4
	6.5	7.1	8.6	6.8	4.6	2.8	1.3	0.4	0.2	0.2	0.3
	7.8	10.9	8.5	6.0	5.3	3.3	1.2	0.5	0.2	0.2	0.2
					SWL = +4.0 FT						
	5.8	4.6	4.7	3.6	3.1	1.6	0.9	0.5	0.3	0.3	0.3
	6.5	7.1	5.7	5.8	5.7	2.9	1.2	0.6	0.3	0.3	0.3
	7.8	10.9	9.9	8.3	6.9	4.5	1.4	0.7	0.5	0.4	0.4
					SWL = +4.4 FT						
	7.6	10.4	10.8	9.3	7.2	5.5	2.4	0.9	0.5	0.5	0.3

(CONTINUED)

TABLE 8 (CONCLUDED)

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
					SWL = +0.9 FT					
357	5.8	4.6	0.2	0.3	0.1	0.3	0.3	0.3	0.3	0.3
	6.5	7.1	0.2	0.1	0.1	0.3	0.3	0.2	0.2	0.2
	7.8	10.9	0.5	0.3	0.3	0.4	0.4	0.2	0.4	0.5
					SWL = +4.0 FT					
	5.8	4.6	0.3	0.3	0.1	0.4	0.5	0.3	0.2	0.2
	6.5	7.1	0.3	0.3	0.3	0.4	0.5	0.2	0.7	0.5
	7.8	10.9	0.5	0.5	0.3	0.6	0.6	0.3	0.4	0.7
					SWL = +4.4 FT					
	7.6	10.4	0.6	0.4	0.5	0.6	0.7	0.3	0.5	0.7

TABLE 9

WAVE HEIGHTS FOR PLANS 5 AND 5A FOR TEST WAVES

FROM 357 DEG DIRECTION

Plan	Test Wave Period sec	Test Wave Height ft	Wave Height, ft Gage 1B	Gage 1A	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7
					SWL = +0.9 FT						
5	5.8	4.6	3.5	3.1	3.4	1.9	0.9	0.4	0.3	0.3	0.3
	6.5	7.1	7.8	6.6	4.2	3.0	1.2	0.4	0.2	0.1	0.2
	7.8	10.9	7.3	5.0	5.8	2.5	0.7	0.3	0.2	0.1	0.1
					SWL = +4.0 FT						
	5.8	4.6	3.7	3.6	2.5	1.5	0.8	0.4	0.2	0.3	0.3
	6.5	7.1	5.3	3.4	6.1	3.0	1.3	0.5	0.4	0.5	0.4
	7.8	10.9	7.4	7.8	8.4	3.8	1.2	0.5	0.4	0.2	0.2
5A		10.9	9.2	6.7	6.3	3.8	1.3	0.4	0.4	0.3	0.3
					SWL = +4.4 FT						
5	7.6	10.4	10.9	9.2	9.3	4.4	1.8	0.6	0.4	0.3	0.3
5A		10.4	5.9	7.3	7.1	3.9	1.6	0.4	0.4	0.3	0.3

(CONTINUED)

TABLE 9 (CONCLUDED)

Test Wave			Wave Height, ft							
Plan	Period sec	Height ft	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
			SWL = +0.9 FT							
5	5.8	4.6	0.1	0.3	0.1	0.3	0.4	0.2	0.2	0.2
	6.5	7.1	0.2	0.1	0.2	0.3	0.3	0.2	0.2	0.2
	7.8	10.9	0.2	0.2	0.2	0.3	0.3	0.1	0.3	0.3
			SWL = +4.0 FT							
	5.8	4.6	0.2	0.3	<0.1	0.4	0.4	0.2	0.1	0.2
	6.5	7.1	0.3	0.3	0.4	0.4	0.5	0.2	0.7	0.6
	7.8	10.9	0.3	0.4	0.2	0.4	0.4	0.2	0.3	0.3
5A		10.9	0.4	0.4	0.3	0.4	0.4	0.2	0.3	0.4
			SWL = +4.4 FT							
5	7.6	10.4	0.4	0.5	0.3	0.6	0.5	0.2	0.3	0.4
5A		10.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4

TABLE 10

WAVE HEIGHTS FOR PLANS 6-6D FOR TEST WAVES

FROM 357 DEG DIRECTION

	Test Wave		Wave Height, ft							
Plan	Period sec	Height ft	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
			SWL = +0.9 FT							
6C	5.8	4.6	2.3	0.8	0.3	0.1	0.1	<0.1	0.1	<0.1
	6.5	7.1	2.6	1.6	0.6	0.2	0.1	0.1	0.1	<0.1
	7.8	10.9	2.5	1.6	0.5	0.2	<0.1	<0.1	<0.1	0.2
			SWL = +4.0 FT							
6		10.9	7.0	4.8	2.2	0.8	0.5	0.4	0.4	0.6
6A		10.9	6.0	3.5	1.1	0.4	0.3	0.3	0.2	0.2
6B		10.9	5.9	2.9	0.9	0.4	0.2	0.2	0.2	0.2
6C	5.8	4.6	1.8	0.6	0.3	0.1	<0.1	0.1	0.1	0.1
	6.5	7.1	4.9	1.9	0.9	0.3	0.3	0.2	0.2	0.2
	7.8	10.9	5.6	2.7	0.9	0.4	0.2	0.1	0.2	0.2
			SWL = +4.4 FT							
6	7.6	10.4	10.3	5.6	2.3	0.7	0.6	0.6	0.4	0.3
6A		10.4	7.5	4.3	1.7	0.7	0.5	0.4	0.2	0.5
6B		10.4	7.2	3.5	1.3	0.5	0.3	0.3	0.2	0.3
6C		10.4	6.2	2.9	1.0	0.3	0.2	0.1	0.1	0.2
6D		10.4	5.5	2.3	1.0	0.3	0.2	0.1	0.1	0.3

(CONTINUED)

TABLE 10 (CONCLUDED)

	Test Wave		Wave Height, ft						
Plan	Period sec	Height ft	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
			SWL = +0.9 FT						
6C	5.8	4.6	0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1
	6.5	7.1	<0.1	<0.1	0.2	0.2	<0.1	0.1	0.2
	7.8	10.9	0.1	0.1	0.2	0.2	<0.1	0.2	0.2
			SWL = +4.0 FT						
6		10.9	0.4	0.4	0.6	0.6	0.4	0.4	0.6
6A		10.9	0.2	0.2	0.3	0.3	0.2	0.2	0.3
6B		10.9	0.3	0.2	0.3	0.3	0.2	0.2	0.3
6C	5.8	4.6	0.2	<0.1	0.2	0.2	<0.1	<0.1	0.1
	6.5	7.1	0.2	0.3	0.3	0.4	0.1	0.5	0.3
	7.8	10.9	0.3	0.2	0.3	0.3	0.1	0.2	0.3
			SWL = +4.4 FT						
6	7.6	10.4	0.3	0.4	0.5	0.4	0.3	0.3	0.4
6A		10.4	0.3	0.5	0.5	0.5	0.3	0.3	0.5
6B		10.4	0.2	0.3	0.4	0.4	0.2	0.2	0.4
6C		10.4	0.2	0.2	0.2	0.2	<0.1	0.1	0.2
6D		10.4	0.1	0.2	0.2	0.2	0.1	0.1	0.2

TABLE 11

WAVE HEIGHTS FOR PLANS 7-7E FOR TEST WAVES

FROM 357 DEG DIRECTION

PLAN	TEST WAVE PERIOD SEC	TEST WAVE HEIGHT FT	WAVE HEIGHT, FT GAGE 1	GAGE 2	GAGE 3	GAGE 4	GAGE 5	GAGE 6	GAGE 7	GAGE 8
SWL = +4.0 FT										
7	7.8	10.9	8.3	4.0	1.4	0.5	0.3	0.2	0.2	0.4
7A		10.9	8.2	3.4	1.2	0.4	0.3	0.2	0.2	0.4
7B		10.9	8.8	3.4	1.2	0.6	0.3	0.2	0.2	0.3
7C		10.9	5.9	2.4	0.8	0.4	0.2	0.2	0.2	0.2
7D		10.9	7.5	2.8	0.9	0.4	0.3	0.3	0.2	0.3
7E		10.9	7.7	3.7	1.3	0.5	0.3	0.2	0.2	0.3
SWL = +4.4 FT										
7	7.6	10.4	9.1	4.1	1.5	0.6	0.4	0.3	0.3	0.4
7A		10.4	8.5	3.5	1.3	0.5	0.3	0.3	0.3	0.3
7B		10.4	7.8	3.6	1.2	0.4	0.2	0.2	0.2	0.3
7C		10.4	5.1	1.8	0.7	0.2	0.2	0.2	0.1	0.2
7D		10.4	7.3	2.3	0.9	0.3	0.2	0.2	0.2	0.3
7E		10.4	8.0	3.5	1.0	0.4	0.3	0.2	0.2	0.3

(CONTINUED)

TABLE 11 (CONCLUDED)

Test Wave			Wave Height, ft						
Plan	Period sec	Height ft	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
			SWL = +4.0 FT						
7	7.8	10.9	0.4	0.3	0.3	0.4	0.2	0.2	0.4
7A		10.9	0.3	0.2	0.3	0.4	0.3	0.2	0.3
7B		10.9	0.3	0.2	0.4	0.4	0.2	0.3	0.4
7C		10.9	0.3	0.2	0.2	0.3	0.2	0.2	0.3
7D		10.9	0.3	0.3	0.3	0.3	0.2	0.2	0.3
7E		10.9	0.3	0.3	0.3	0.4	0.3	0.2	0.3
			SWL = +4.4 FT						
7	7.6	10.4	0.3	0.4	0.4	0.4	0.3	0.3	0.4
7A		10.4	0.2	0.2	0.3	0.3	0.2	0.2	0.3
7B		10.4	0.2	0.2	0.3	0.3	0.2	0.2	0.3
7C		10.4	0.2	0.2	0.2	0.2	0.2	0.1	0.2
7D		10.4	0.2	0.2	0.2	0.3	0.1	0.2	0.2
7E		10.4	0.2	0.3	0.3	0.3	0.2	0.2	0.2

TABLE 12

WAVE HEIGHTS FOR PLAN 2F

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 1A	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7
					SWL = +0.9 FT					
287	6.6	5.6	5.7	4.8	1.6	0.7	0.4	0.1	0.1	0.1
	7.4	7.5	5.8	4.1	1.4	0.5	0.2	0.1	0.1	0.1
	9.0	10.9	6.7	2.7	1.9	0.8	0.3	0.2	0.2	0.2
357	5.8	4.6	4.8	3.2	1.3	0.8	0.4	0.2	0.2	0.2
	6.5	7.1	8.0	6.9	2.4	1.1	0.5	0.3	0.4	0.4
	7.8	10.9	6.9	5.6	3.0	1.0	0.4	0.2	0.2	0.2
19	5.5	4.4	2.6	2.0	0.8	0.4	0.2	<0.1	<0.1	0.1
	6.2	6.3	6.0	5.5	1.8	0.9	0.3	0.3	0.2	0.3
	7.1	9.1	6.6	4.4	2.2	0.9	0.3	0.2	0.2	0.2
					SWL = +4.0 FT					
287	6.6	5.6	2.9	3.6	2.0	1.2	0.5	0.4	0.2	0.2
	7.4	7.5	7.0	5.6	2.7	1.1	0.4	0.3	0.2	0.2
	9.0	10.9	7.5	3.8	1.5	0.7	0.5	0.3	0.2	0.2
357	5.8	4.6	3.7	2.9	1.0	0.5	0.3	0.2	0.2	0.2
	6.5	7.1	7.9	5.2	1.9	0.9	0.4	0.3	0.2	0.3
	7.8	10.9		4.1	2.5	0.8	0.3	0.2	0.2	0.2
19	5.5	4.4	3.6	3.0	1.4	0.6	0.4	0.2	0.2	0.2
	6.2	6.3	5.3	4.6	1.8	0.8	0.4	0.5	0.4	0.3
	7.1	9.1	8.5	5.3	2.7	0.9	0.4	0.2	0.2	0.2
					SWL = +4.4 FT					
287	8.8	10.4	8.1	3.6	1.5	0.5	0.4	0.2	0.2	0.2
357	7.6	10.4		5.2	3.4	1.2	0.4	0.3	0.3	0.2

(CONTINUED)

TABLE 12 (CONCLUDED)

Test Wave			Wave Height, ft							
Direction deg	Period sec	Height ft	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
			SWL = +0.9 FT							
287	6.6	5.6	0.1	0.1	0.2	0.3	0.4	0.2	0.2	0.2
	7.4	7.5	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2
	9.0	10.9	0.3	0.2	0.2	0.4	0.3	0.2	0.2	0.3
357	5.8	4.6	0.2	0.3	<0.1	0.3	0.4	0.2	0.2	0.3
	6.5	7.1	0.2	0.2	0.2	0.5	0.8	0.4	0.4	0.3
	7.8	10.9	0.2	0.3	0.2	0.3	0.3	0.1	0.3	0.3
19	5.5	4.4	0.1	0.2	<0.1	0.2	0.1	<0.1	<0.1	0.1
	6.2	6.3	0.1	0.3	0.2	0.3	0.4	0.2	0.3	0.3
	7.1	9.1	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3
			SWL = +4.0 FT							
287	6.6	5.6	0.3	0.2	0.3	0.3	0.4	0.2	0.4	0.5
	7.4	7.5	0.3	0.2	0.4	0.4	0.4	0.2	0.4	0.3
	9.0	10.9	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3
357	5.8	4.6	0.2	0.3	<0.1	0.4	0.4	0.2	0.2	0.2
	6.5	7.1	0.2	0.3	0.3	0.3	0.5	0.2	0.7	0.4
	7.8	10.9	0.4	0.2	0.2	0.3	0.2	0.2	0.2	0.3
19	5.5	4.4	0.2	0.3	0.2	0.3	0.4	0.2	0.3	0.4
	6.2	6.3	0.2	0.3	0.3	0.3	0.5	0.2	0.4	0.5
	7.1	9.1	0.3	0.2	0.3	0.3	0.3	0.2	0.4	0.3
			SWL = +4.4 FT							
287	8.8	10.4	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.3
357	7.6	10.4	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.3

Table 13

Wave Heights and Wave Trough Elevations For Plan 2F

+0.3 ft swl

Test Wave			Wave Height, ft		Wave Trough Elevation*	
Direction deg	Period sec	Height ft	Gage 1B	Gage 1A	Gage 1B	Gage 1A
287	7.4	7.5	5.8	4.8	-1.5	-1.8
	9.0	10.9	9.5	6.6	-2.3	-1.7
357	6.5	7.1	8.7	7.8	-3.0	-2.2
	7.8	10.9	9.4	7.2	-2.1	-1.7
19	6.2	6.3	6.2	5.9	-2.1	-1.9
	7.1	9.1	5.9	5.5	-2.0	-1.4

* Elevation referenced to LWD.

TABLE 14

WAVE HEIGHTS FOR PLAN 2I

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 1A	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7
SWL = +0.9 FT										
287	6.6	5.6	5.7	4.6	1.7	0.8	0.4	0.2	0.2	0.2
	7.4	7.5	5.5	4.0	1.6	0.6	0.2	0.1	0.1	0.1
	9.0	10.9	7.1	2.2	1.9	0.8	0.3	0.2	0.2	0.2
357	5.8	4.6	4.1	2.9	1.1	0.7	0.3	0.2	0.2	0.2
	6.5	7.1	7.1	5.2	2.9	1.1	0.5	0.2	0.2	0.3
	7.8	10.9	6.8	5.6	2.9	1.0	0.4	0.2	0.1	0.1
19	5.5	4.4	2.7	2.4	1.0	0.5	0.3	0.1	<0.1	0.2
	6.2	6.3	6.3	5.3	2.0	1.1	0.5	0.3	0.3	0.4
	7.1	9.1	5.6	3.7	2.2	0.8	0.4	0.2	0.2	0.2
SWL = +4.0 FT										
287	6.6	5.6	3.3	4.0	2.6	1.3	0.6	0.5	0.3	0.2
	7.4	7.5	6.1	4.7	2.0	0.9	0.4	0.2	0.2	0.2
	9.0	10.9	8.0	3.3	1.6	0.7	0.5	0.3	0.3	0.2
357	5.8	4.6	3.5	3.3	1.1	0.6	0.3	0.2	0.2	0.3
	6.5	7.1	5.8	4.4	1.7	0.8	0.4	0.3	0.2	0.3
	7.8	10.9	8.6	5.3	3.0	1.2	0.5	0.3	0.3	0.3
19	5.5	4.4	3.1	2.7	1.3	0.5	0.4	0.2	0.2	0.2
	6.2	6.3	4.8	4.8	2.2	0.9	0.4	0.4	0.4	0.4
	7.1	9.1	6.6	4.7	2.6	1.1	0.5	0.2	0.3	0.2
SWL = +4.4 FT										
287	8.8	10.4	8.0	3.7	1.5	0.8	0.4	0.3	0.2	0.2
357	7.6	10.4	9.9	6.7	3.9	1.9	0.5	0.4	0.5	0.4

(CONTINUED)

TABLE 14 (CONCLUDED)

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
					SWL = +0.9 FT					
287	6.6	5.6	0.2	0.1	0.1	0.3	0.4	0.2	0.2	0.2
	7.4	7.5	0.1	0.1	0.1	0.2	0.2	<0.1	0.2	0.2
	9.0	10.9	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.3
357	5.8	4.6	0.2	0.2	<0.1	0.2	0.3	0.2	0.2	0.2
	6.5	7.1	0.2	0.2	0.2	0.5	0.6	0.2	0.3	0.3
	7.8	10.9	0.2	0.2	0.1	0.3	0.3	0.1	0.3	0.3
19	5.5	4.4	0.1	0.2	0.1	0.3	0.2	<0.1	<0.1	0.1
	6.2	6.3	0.2	0.4	0.3	0.4	0.6	0.2	0.3	0.3
	7.1	9.1	0.2	0.2	0.1	0.3	0.3	0.1	0.2	0.2
					SWL = +4.0 FT					
287	6.6	5.6	0.4	0.3	0.4	0.5	0.5	0.3	0.6	0.6
	7.4	7.5	0.3	0.2	0.3	0.4	0.4	0.2	0.3	0.3
	9.0	10.9	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3
357	5.8	4.6	0.3	0.3	0.1	0.4	0.4	0.3	0.2	0.2
	6.5	7.1	0.2	0.2	0.2	0.3	0.4	0.2	0.5	0.3
	7.8	10.9	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.3
19	5.5	4.4	0.2	0.3	0.2	0.2	0.4	0.2	0.3	0.3
	6.2	6.3	0.2	0.4	0.4	0.3	0.6	0.2	0.4	0.5
	7.1	9.1	0.3	0.3	0.3	0.3	0.4	0.3	0.5	0.3
					SWL = +4.4 FT					
287	8.8	10.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3
357	7.6	10.4	0.3	0.3	0.3	0.4	0.3	0.4	0.3	0.3

TABLE 15

WAVE HEIGHTS OBTAINED ALONG THE SHORELINE EAST OF THE HARBOR LOCATION WITH PLAN 2F INSTALLED

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT GAGE 16	GAGE 17	GAGE 18	GAGE 19	GAGE 20	GAGE 21	GAGE 22	GAGE 23
					SWL = +0.9 FT					
287	6.6	5.6	2.5	4.4	2.4	1.8	2.3	4.2	2.1	3.7
	7.4	7.5	2.7	4.0	2.8	3.9	2.9	3.6	3.1	3.3
	9.0	10.9	3.1	4.4	3.6	4.3	3.8	4.6	3.0	3.4
357	5.8	4.6	3.0	4.1	2.8	2.6	3.5	4.2	2.8	4.4
	6.5	7.1	3.3	4.6	3.2	4.1	3.1	4.5	2.9	2.9
	7.8	10.9	3.7	5.1	3.4	3.8	4.0	4.8	3.3	3.9
19	5.5	4.4	2.8	5.1	2.7	5.1	2.5	3.4	2.3	3.8
	6.2	6.3	3.5	4.0	4.1	4.5	2.9	4.3	3.0	3.8
	7.1	9.1	3.2	5.2	3.9	4.5	3.3	4.4	2.9	4.1
					SWL = +4.0 FT					
287	6.6	5.6	2.8	5.2	4.3	4.2	4.4	5.1	4.0	2.8
	7.4	7.5	4.7	6.0	5.3	5.8	5.0	6.8	5.3	5.4
	9.0	10.9	6.1	6.6	5.0	6.7	4.3	6.1	5.3	5.6
357	5.8	4.6	4.6	5.0	5.0	6.3	4.9	6.4	5.2	5.4
	6.5	7.1	5.4	7.0	5.6	6.7	5.2	6.4	5.4	4.0
	7.8	10.9	6.4	7.4	5.9	6.2	5.9	7.8	5.2	5.8
19	5.5	4.4	5.1	4.9	5.7	4.9	4.9	3.2	5.0	2.6
	6.2	6.3	5.3	6.9	5.3	7.1	6.8	7.0	5.2	4.8
	7.1	9.1	5.2	6.4	5.7	6.4	5.2	6.4	5.4	6.7
					SWL = +4.4 FT					
287	8.8	10.4	6.4	6.5	5.4	5.8	5.4	7.0	5.3	6.5
357	7.6	10.4	5.8	6.9	5.8	7.4	6.1	7.3	5.1	5.2

(CONTINUED)

TABLE 15 (CONCLUDED)

Test Wave Direction DEG	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 16	Gage 17	Gage 18	Gage 19	Gage 20	Gage 21	Gage 22	Gage 23
					SWL = +5.3 FT					
287	6.6	5.6	4.2	6.5	3.6	4.0	4.3	3.2	3.5	3.1
	7.4	7.5	6.4	7.0	4.3	4.3	6.0	6.5	6.7	6.5
	9.0	10.9	6.0	6.1	5.9	6.1	5.5	6.8	6.1	6.4
357	5.8	4.6	6.3	4.9	5.8	7.1	4.7	7.7	4.2	6.4
	6.5	7.1	5.1	9.0	7.9	6.0	6.4	7.4	5.6	5.6
	7.8	10.9	7.0	7.3	6.2	6.6	7.7	7.7	6.6	5.6
19	5.5	4.4	5.2	5.2	6.0	5.1	5.2	3.6	6.4	3.6
	6.2	6.3	8.0	8.4	7.5	9.9	6.7	7.8	6.5	5.8
	7.1	9.1	6.1	9.9	7.5	7.5	8.1	7.0	6.0	6.2

TABLE 16

COMPARISON WAVE HEIGHTS FOR PLANS 2F,2H AND 2J

FOR TEST WAVES FROM 357 DEG DIRECTION

	Test Wave		Wave Height, ft							
Plan	Period sec	Height ft	Gage 1A	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7
				SWL = +4.4 FT						
2F	7.6	10.4		5.2	3.4	1.2	0.4	0.3	0.3	0.2
2H		10.4		4.5	2.7	1.1	0.2	0.3	0.2	0.2
2J		10.4	10.2	6.4	4.0	1.6	0.6	0.4	0.4	0.3
				SWL = +5.3 FT						
2F	7.8	10.9	10.2	7.1	3.9	1.6	0.5	0.6	0.3	0.4
2H		10.9	10.6	5.8	3.3	1.5	0.5	0.6	0.3	0.4
2J		10.9	10.4	5.5	3.7	1.3	0.3	0.5	0.3	0.3

(CONTINUED)

TABLE 16 (CONCLUDED)

	Test Wave		Wave Height, ft							
Plan	Period sec	Height ft	Gage 8	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
					SWL = +4.4 FT					
2F	7.6	10.4	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.3
2H		10.4	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2
2J		10.4	0.4	0.3	0.3	0.4	0.3	0.4	0.3	0.3
					SWL = +5.3 FT					
2F	7.8	10.9	0.4	0.2	0.4	0.4	0.5	0.5	0.5	0.3
2H		10.9	0.4	0.2	0.5	0.3	0.4	0.6	0.5	0.2
2J		10.9	0.4	0.2	0.3	0.2	0.3	0.4	0.4	0.2

TABLE 17

WAVE HEIGHTS FOR PLAN 2H

TEST WAVE			WAVE HEIGHT, FT							
DIRECTION DEG	PERIOD SEC	HEIGHT FT	GAGE 1A	GAGE 1	GAGE 2	GAGE 3	GAGE 4	GAGE 5	GAGE 6	GAGE 7
			SWL = +0.9 FT							
287	6.6	5.6	5.7	3.3	1.2	0.5	0.2	0.1	0.1	0.1
	7.4	7.5	5.2	2.6	0.9	0.3	0.1	<0.1	<0.1	<0.1
	9.0	10.9	5.8	3.3	1.9	0.6	0.4	0.2	0.2	0.2
357	7.8	10.9	5.7	4.5	2.2	0.8	0.3	0.1	0.1	0.1
	6.5	7.1	6.8	4.3	2.7	1.0	0.4	0.2	0.2	0.3
	5.8	4.6	4.6	3.0	1.1	0.5	0.3	0.2	0.1	0.2
19	5.5	4.4	2.4	1.8	0.5	0.2	0.1	<0.1	<0.1	<0.1
	6.2	6.3	5.8	3.7	1.1	0.6	0.3	0.2	0.2	0.2
	7.1	9.1	6.1	3.3	1.7	0.6	0.3	0.1	0.1	0.1
			SWL = +4.0 FT							
287	6.6	5.6	1.9	2.5	1.2	0.6	0.3	0.2	0.1	0.2
	7.4	7.5	7.3	3.9	1.5	0.7	0.3	0.2	0.2	0.2
	9.0	10.9	6.7	2.2	1.7	0.6	0.4	0.2	0.2	0.2
357	5.8	4.6	3.3	2.5	0.6	0.3	0.2	0.1	0.1	0.2
	6.5	7.1	6.9	4.6	1.6	0.7	0.3	0.2	0.1	0.2
	7.8	10.9	7.0	5.6	2.7	1.0	0.4	0.3	0.3	0.3
19	5.5	4.4	2.7	2.2	0.9	0.4	0.4	0.1	0.1	0.1
	6.2	6.3	4.5	2.7	1.2	0.4	0.3	0.2	0.2	0.1
	7.1	9.1	7.4	4.2	2.3	0.8	0.4	0.1	0.1	0.2
			SWL = +4.4 FT							
287	8.8	10.4	5.6	2.3	1.7	0.7	0.4	0.2	0.2	0.2
357	7.6	10.4		4.5	2.7	1.1	0.2	0.3	0.2	0.2
			SWL = +5.3 FT							
287	6.6	5.6	2.3	3.3	2.2	1.2	0.6	0.4	0.2	0.3
	7.4	7.5	9.7	6.1	1.7	0.7	0.3	0.2	0.2	0.1
	9.0	10.9	6.8	2.5	2.2	1.0	0.4	0.2	0.3	0.2
357	5.8	4.6	3.6	2.7	0.8	0.3	0.2	0.2	0.1	0.2
	6.5	7.1	5.8	3.8	1.4	0.6	0.3	0.2	0.1	0.2
	7.8	10.9	10.6	5.8	3.3	1.5	0.5	0.6	0.3	0.4
19	5.5	4.4	3.5	2.9	1.3	0.6	0.5	0.2	0.3	0.2
	6.2	6.3	4.5	3.4	1.4	0.6	0.4	0.3	0.3	0.2
	7.1	9.1	8.5	4.7	2.2	0.8	0.4	0.2	0.2	0.2

(CONTINUED)

TABLE 17 (CONCLUDED)

TEST WAVE			WAVE HEIGHT, FT							
DIRECTION DEG	PERIOD SEC	HEIGHT FT	GAGE 8	GAGE 9	GAGE 10	GAGE 11	GAGE 12	GAGE 13	GAGE 14	GAGE 15
			SWL = +0.9 FT							
287	6.6	5.6	0.2	<0.1	<0.1	0.2	0.2	0.1	0.2	<0.1
	7.4	7.5	0.1	<0.1	<0.1	0.1	0.1	<0.1	0.1	0.2
	9.0	10.9	0.3	0.1	0.2	0.3	0.3	0.2	0.2	0.3
357	7.8	10.9	0.2	0.2	0.1	0.3	0.2	<0.1	0.2	0.3
	6.5	7.1	0.2	0.1	0.2	0.4	0.4	0.2	0.2	0.4
	5.8	4.6	0.1	0.2	<0.1	0.3	0.3	0.2	0.2	0.2
19	5.5	4.4	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1
	6.2	6.3	0.1	0.1	0.2	0.2	0.3	0.1	0.2	0.2
	7.1	9.1	0.1	0.1	0.1	0.2	0.2	<0.1	0.2	0.1
			SWL = +4.0 FT							
287	6.6	5.6	0.2	0.2	0.2	0.2	0.3	0.1	0.4	0.3
	7.4	7.5	0.2	0.2	0.3	0.3	0.3	0.1	0.2	0.2
	9.0	10.9	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3
357	5.8	4.6	0.1	0.1	<0.1	0.2	0.2	0.1	<0.1	0.1
	6.5	7.1	0.2	0.2	0.2	0.2	0.3	0.1	0.5	0.3
	7.8	10.9	0.4	0.2	0.2	0.3	0.3	0.3	0.2	0.3
19	5.5	4.4	0.2	0.3	0.1	0.2	0.2	0.2	0.2	0.2
	6.2	6.3	0.1	0.3	0.2	0.2	0.3	0.1	0.3	0.2
	7.1	9.1	0.2	0.2	0.2	0.3	0.3	0.2	0.4	0.3
			SWL = +4.4 FT							
287	8.8	10.4	0.2	0.3	0.2	0.3	0.3	0.2	0.3	0.3
357	7.6	10.4	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.2
			SWL = +5.3 FT							
287	6.6	5.6	0.3	0.4	0.4	0.5	0.5	0.3	0.6	0.5
	7.4	7.5	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.2
	9.0	10.9	0.3	0.2	0.2	0.3	0.3	0.2	0.2	0.3
357	5.8	4.6	<0.1	0.1	0.1	0.1	0.2	0.1	<0.1	0.2
	6.5	7.1	0.1	0.3	0.2	0.3	0.4	0.2	0.4	0.3
	7.8	10.9	0.4	0.2	0.5	0.3	0.4	0.6	0.5	0.2
19	5.5	4.4	0.2	0.3	0.2	0.4	0.3	0.2	0.2	0.3
	6.2	6.3	0.3	0.4	0.2	0.2	0.4	0.2	0.5	0.4
	7.1	9.1	0.2	0.2	0.3	0.3	0.4	0.3	0.4	0.3

TABLE 18

WAVE HEIGHTS FOR PLAN 2H FOR TEST WAVES

FROM 357 DEG WITH WETLAND DISCHARGES

Test Wave Discharge CFS	Test Wave Period SEC	Test Wave Height FT	Wave Height, FT Gage 1A	Gage 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage 8
					SWL = +0.9 FT						
65	5.8	4.6	4.7	2.9	1.0	0.5	0.3	0.2	0.1	0.2	0.2
	6.5	7.1	6.9	5.6	2.8	0.9	0.4	0.2	0.1	0.2	0.2
	7.8	10.9	5.7	4.0	2.2	0.8	0.3	0.1	0.1	0.1	0.2
800	5.8	4.6	3.7	2.6	0.7	0.3	0.1	0.1	<0.1	0.1	0.1
	6.5	7.1	9.1	6.1	2.2	0.9	0.4	0.2	0.2	0.2	0.2
	7.8	10.9	7.0	5.5	2.3	0.7	0.2	0.1	0.1	0.1	0.2
					SWL = +4.0 FT						
65	5.8	4.6	3.6	2.5	0.7	0.4	0.2	0.1	0.1	0.2	0.1
	6.5	7.1	6.3	4.1	1.5	0.7	0.4	0.2	0.1	0.2	0.2
	7.8	10.9	7.6	4.2	2.6	1.1	0.5	0.4	0.3	0.3	0.4
800	5.8	4.6	4.5	3.0	1.0	0.4	0.2	0.2	0.1	0.2	0.2
	6.5	7.1	6.7	4.8	1.7	0.9	0.5	0.2	0.2	0.2	0.2
	7.8	10.9	8.3	4.7	2.5	1.0	0.5	0.3	0.2	0.2	0.3
					SWL = +4.4 FT						
65	7.6	10.4	7.8	5.7	2.6	1.2	0.4	0.3	0.3	0.3	0.4
800		10.4	7.7	6.1	2.5	1.0	0.4	0.3	0.3	0.2	0.3
					SWL = +5.3 FT						
65	5.8	4.6	3.3	2.4	0.7	0.3	0.1	0.2	0.1	0.2	<0.1
	6.5	7.1	6.4	4.1	1.5	0.6	0.3	0.2	0.2	0.2	0.1
	7.8	10.9	11.5	7.4	3.6	1.5	0.4	0.6	0.4	0.4	0.5
800	5.8	4.6	3.3	2.2	0.7	0.2	0.1	<0.1	<0.1	0.1	<0.1
	6.5	7.1	6.6	4.2	1.6	0.7	0.4	0.2	0.1	0.3	0.2
	7.8	10.9	11.7	7.7	3.5	1.4	0.5	0.5	0.4	0.4	0.5

(CONTINUED)

TABLE 18 (CONCLUDED)

Test Wave Discharge cfs	Test Wave Period sec	Test Wave Height ft	Wave Height, ft Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
					SWL = +0.9 FT				
65	5.8	4.6	0.2	<0.1	0.3	0.3	0.2	0.2	0.2
	6.5	7.1	0.2	0.2	0.3	0.4	0.2	0.2	0.4
	7.8	10.9	0.2	0.1	0.2	0.2	<0.1	0.2	0.3
800	5.8	4.6	0.1	<0.1	0.2	0.2	<0.1	<0.1	0.2
	6.5	7.1	0.2	0.2	0.4	0.4	0.2	0.3	0.3
	7.8	10.9	0.1	0.1	0.2	0.2	0.1	0.2	0.3
					SWL = +4.0 FT				
65	5.8	4.6	0.2	<0.1	0.2	0.2	0.2	<0.1	0.1
	6.5	7.1	0.3	0.2	0.3	0.3	0.1	0.5	0.3
	7.8	10.9	0.3	0.3	0.3	0.4	0.3	0.3	0.3
800	5.8	4.6	0.2	<0.1	0.2	0.2	0.2	<0.1	0.1
	6.5	7.1	0.3	0.2	0.3	0.4	0.1	0.5	0.3
	7.8	10.9	0.2	0.3	0.2	0.3	0.3	0.3	0.3
					SWL = +4.4 FT				
65	7.6	10.4	0.2	0.3	0.3	0.4	0.3	0.3	0.3
800		10.4	0.2	0.3	0.3	0.3	0.3	0.3	0.3
					SWL = +5.3 FT				
65	5.8	4.6	0.1	0.1	<0.1	0.2	0.1	<0.1	0.2
	6.5	7.1	0.4	0.2	0.3	0.4	0.2	0.5	0.3
	7.8	10.9	0.2	0.5	0.3	0.4	0.6	0.5	0.2
800	5.8	4.6	0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1
	6.5	7.1	0.3	0.3	0.3	0.4	0.3	0.4	0.3
	7.8	10.9	0.2	0.5	0.3	0.4	0.5	0.5	0.3

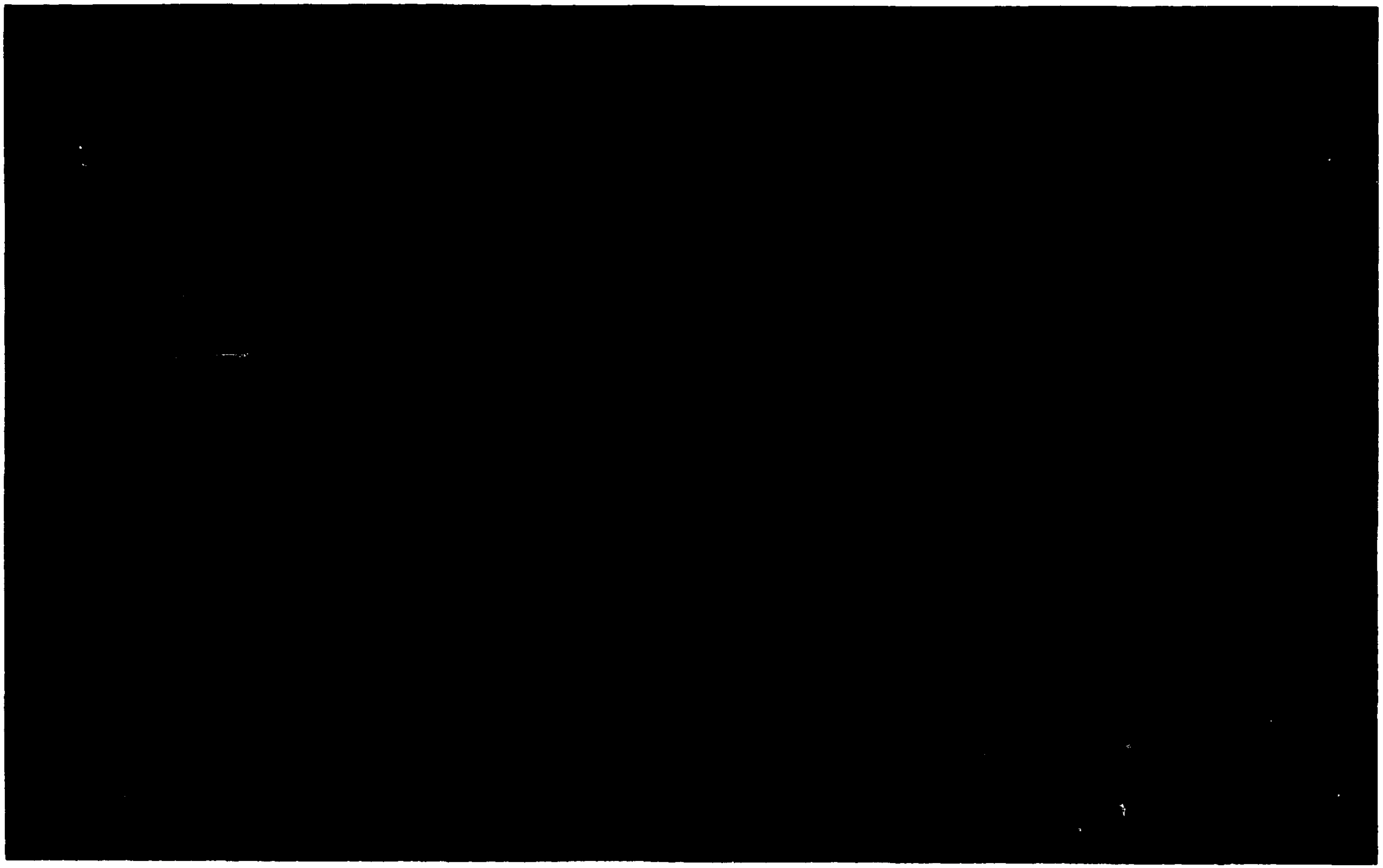


Photo 1. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.4-sec, 7.5-ft waves from 287 deg; +0.9 ft swl

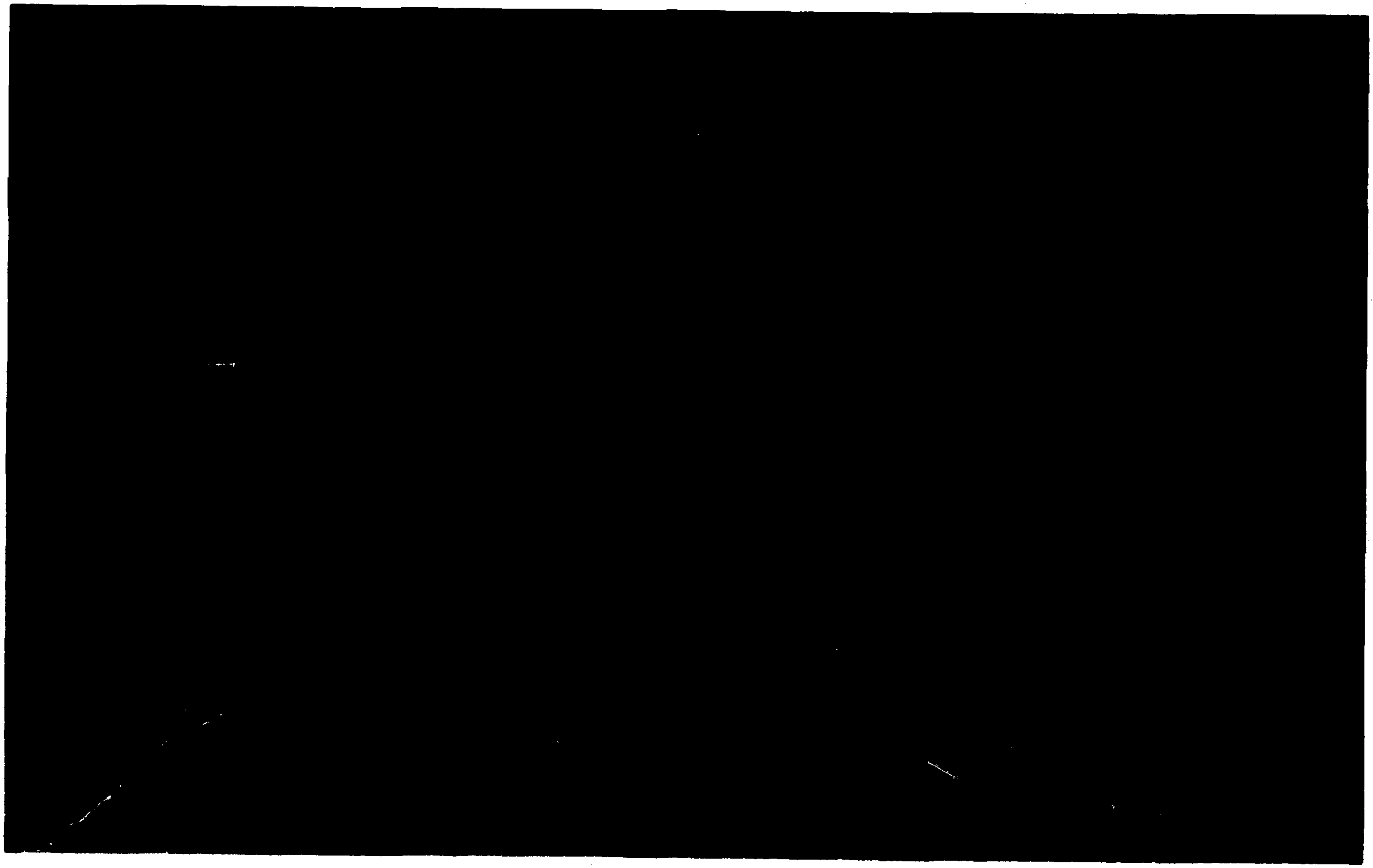


Photo 2. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 9-sec, 10.9-ft waves from 287 deg; +0.9 ft swl

Photo 3. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 6.6-sec, 5.6-ft waves from 287 deg; +4.0 ft swl

Photo 4. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.4-sec, 7.5-ft waves from 287 deg; +4.0 ft swl

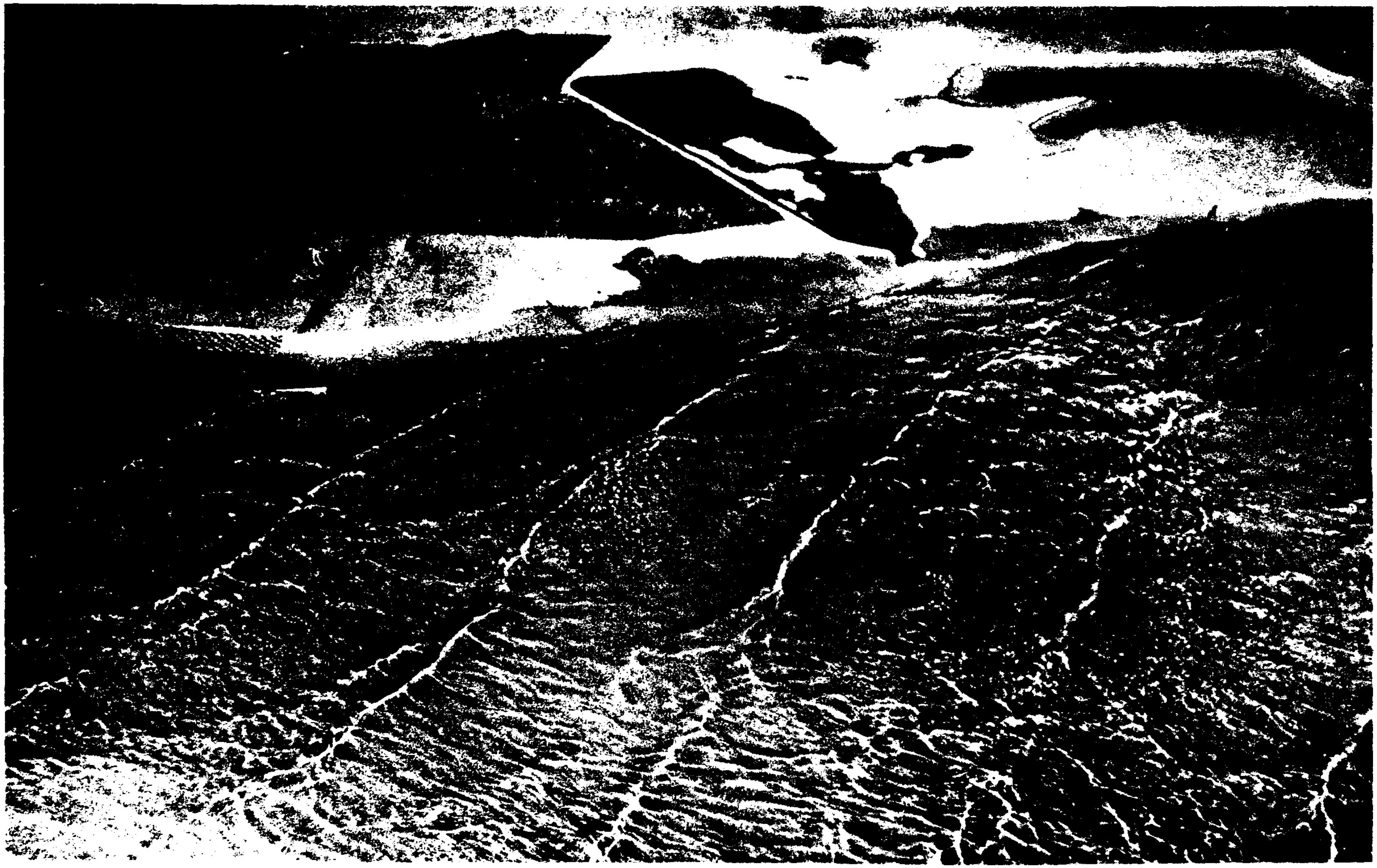


Photo 5. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 9-sec, 10.9-ft waves from 287 deg; +4.0 ft swl

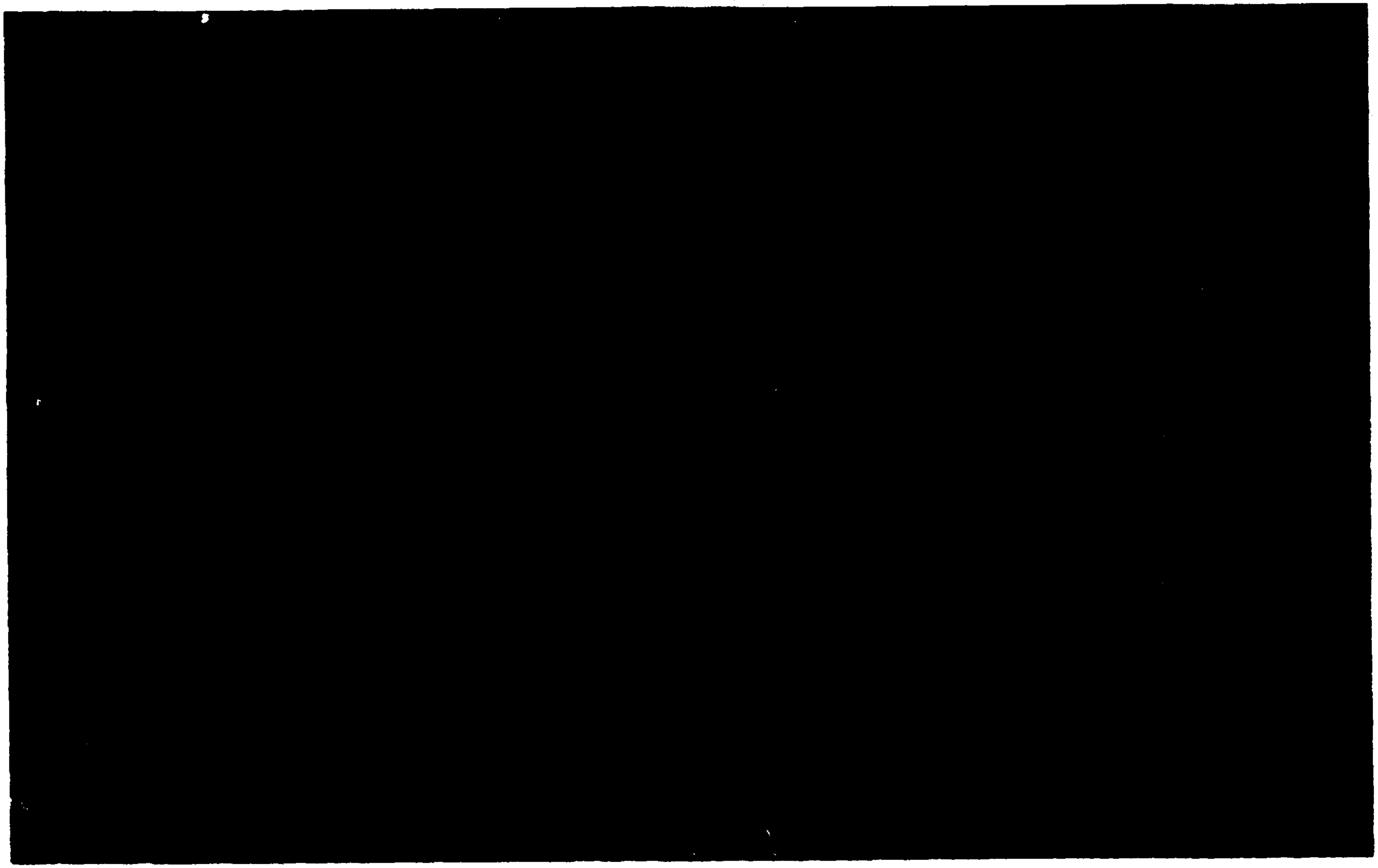


Photo 6. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 8.8-sec, 10.4-ft waves from 287 deg; +4.4 ft swl

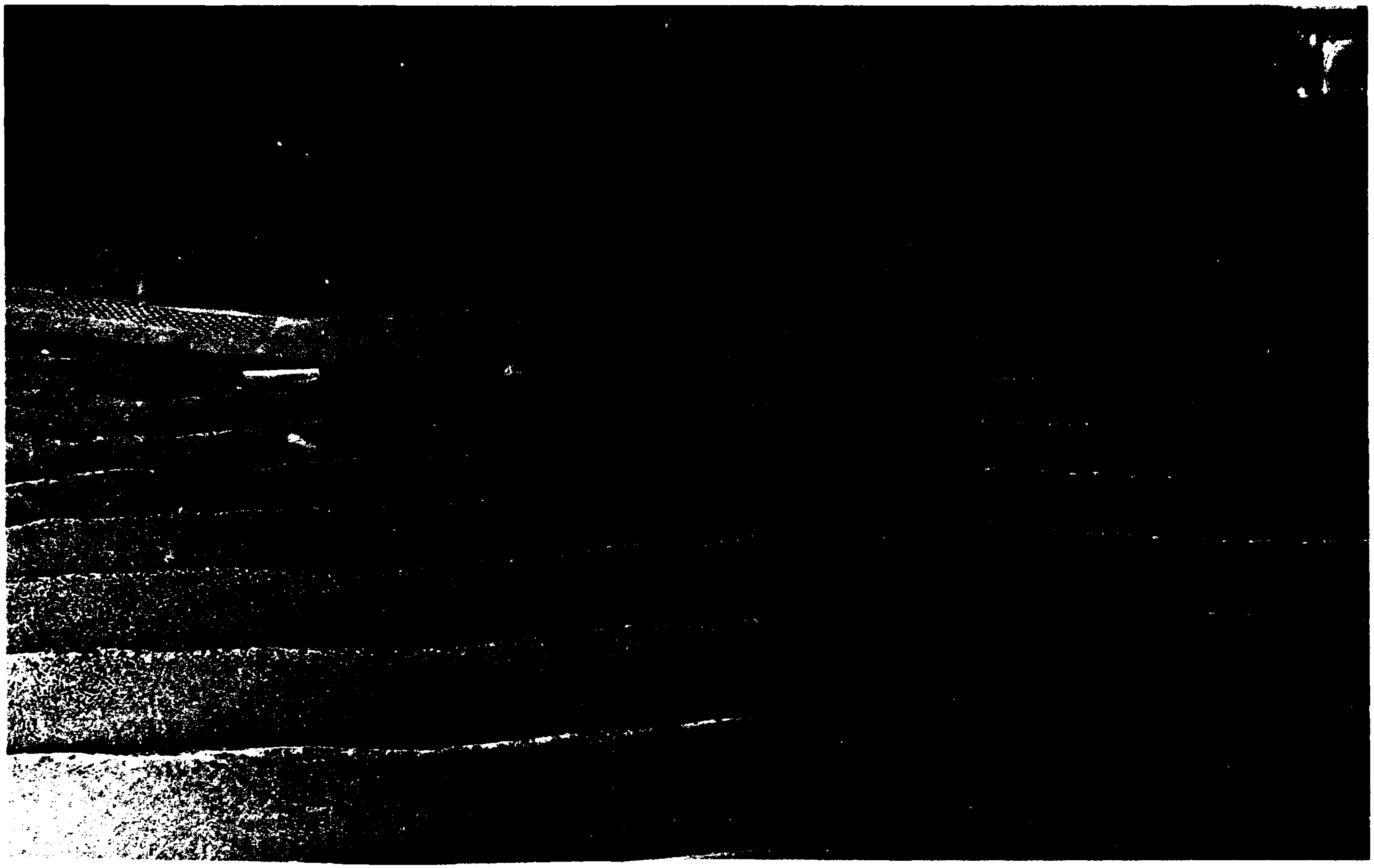


Photo 7. Typical wave patterns, current patterns, and currrent magnitudes (prototype feet per second) for existing conditions; 5.8-sec, 4.6-ft waves from 357 deg; +0.9 ft swl

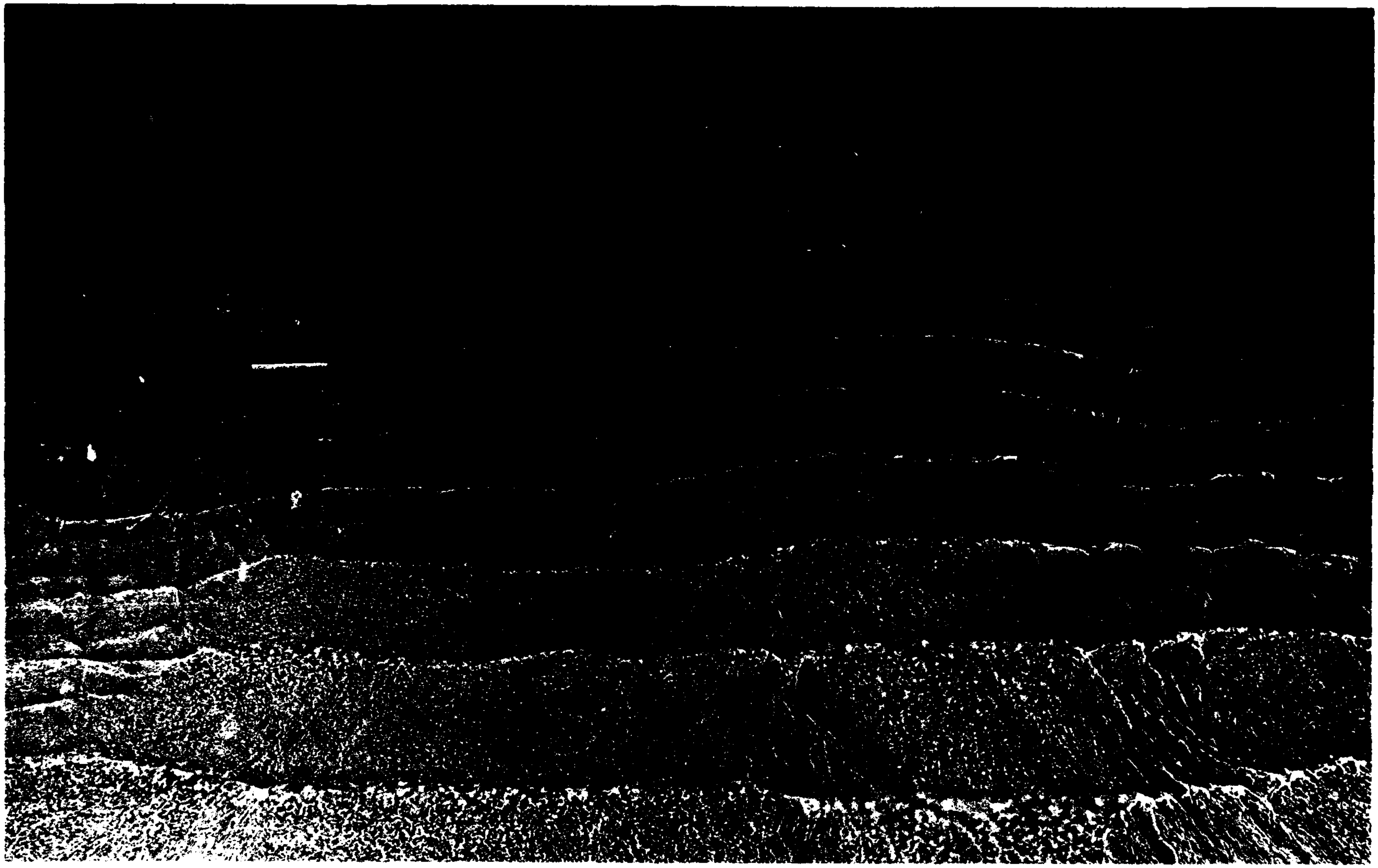


Photo 8. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 6.5-sec, 7.1-ft waves from 357 deg; +0.9 ft swl

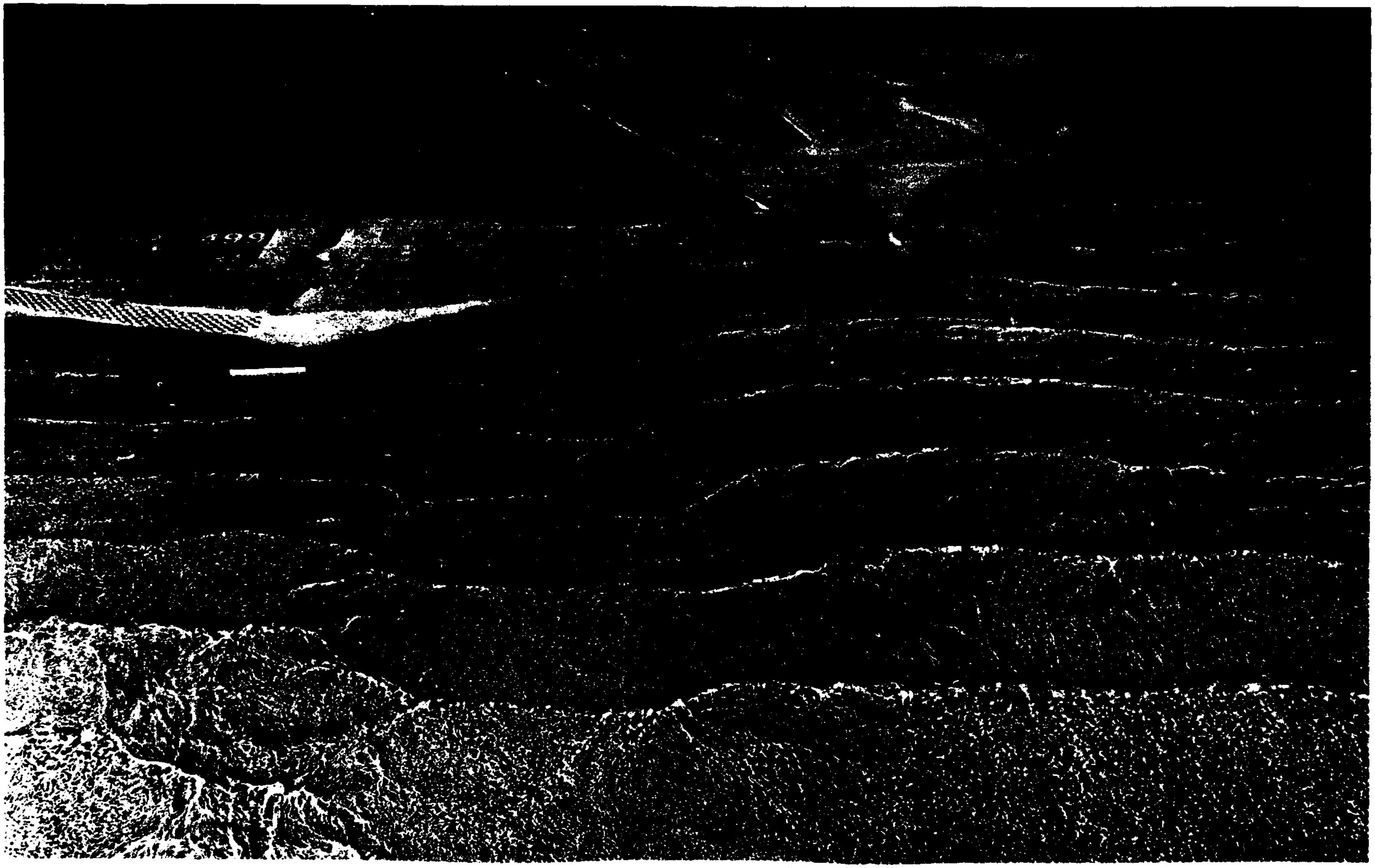


Photo 9. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.8-sec, 10.9-ft waves from 357 deg; +0.9 ft swl

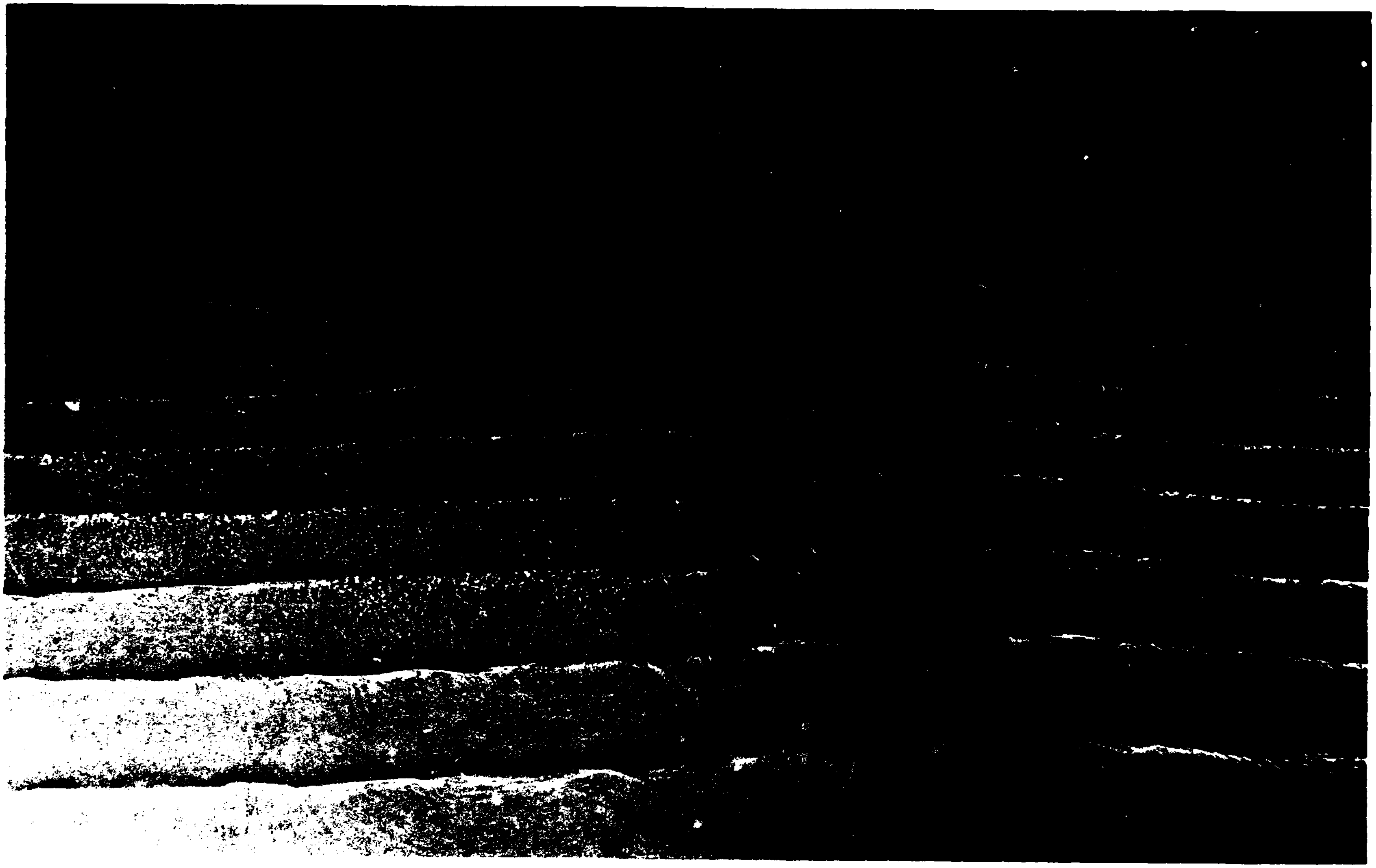


Photo 10. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 5.8-sec, 4.6-ft waves from 357 deg; +4.0 ft swl

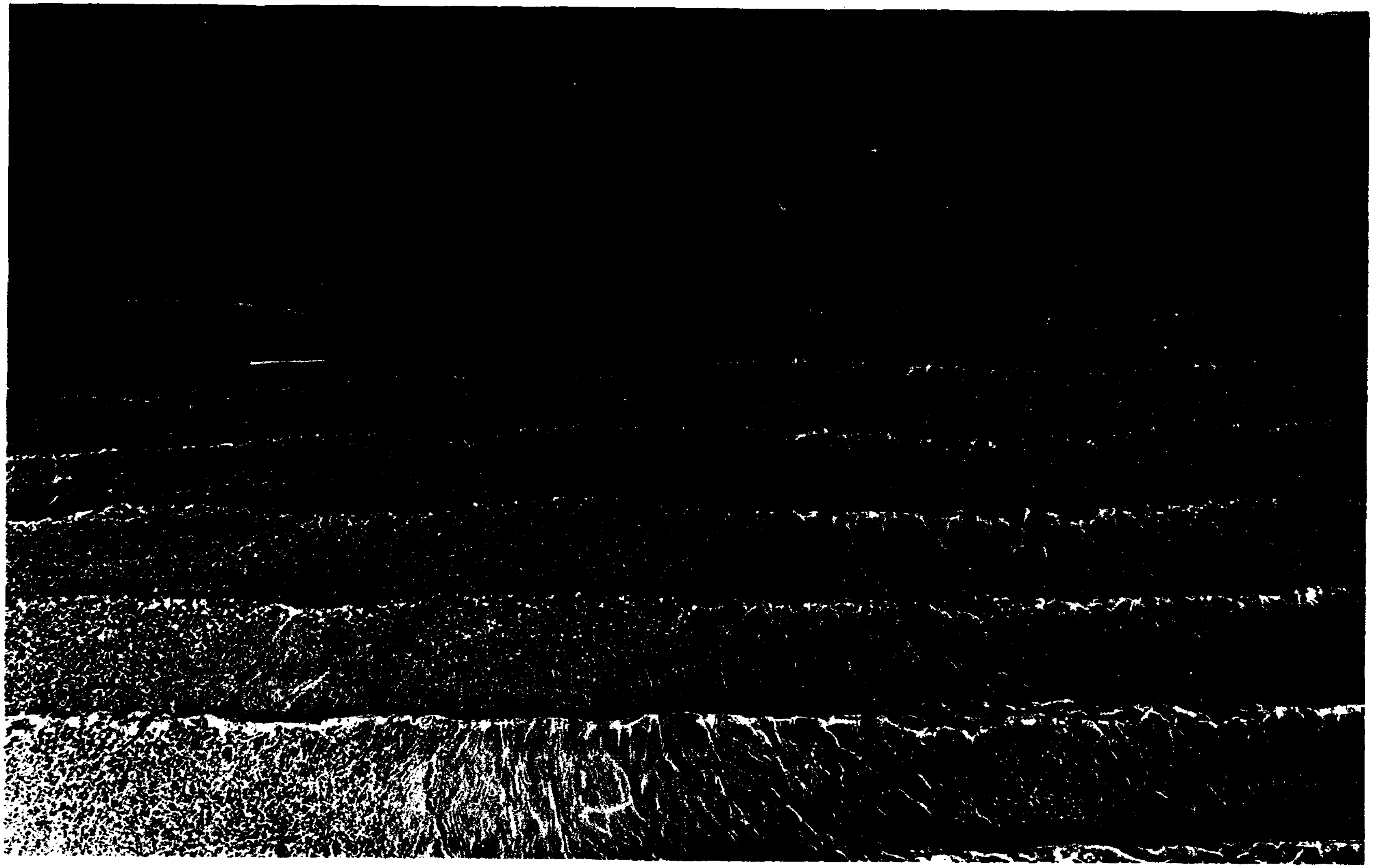


Photo 11. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 6.5-sec, 7.1-ft waves from 357 deg; +4.0 ft swl

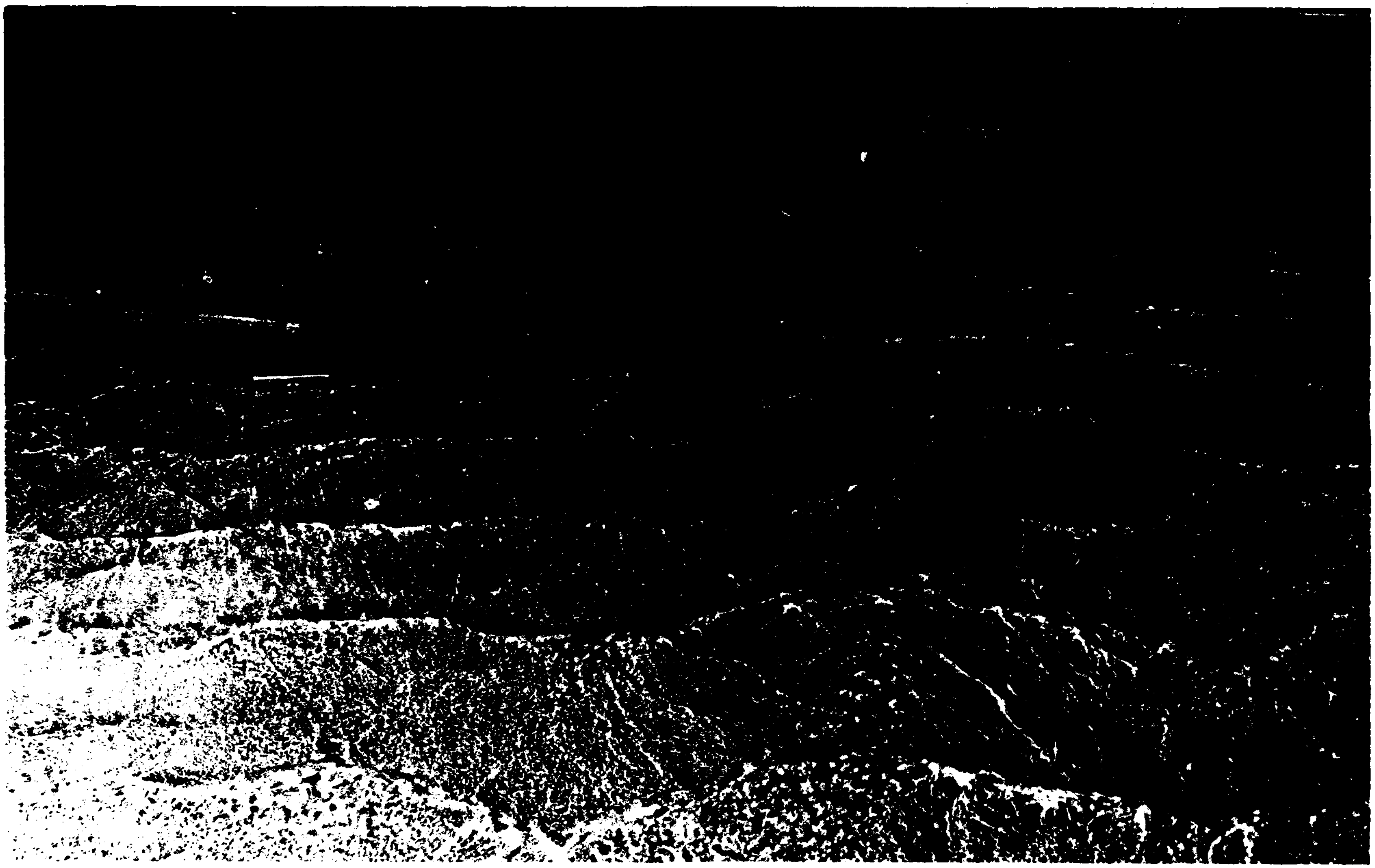


Photo 12. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

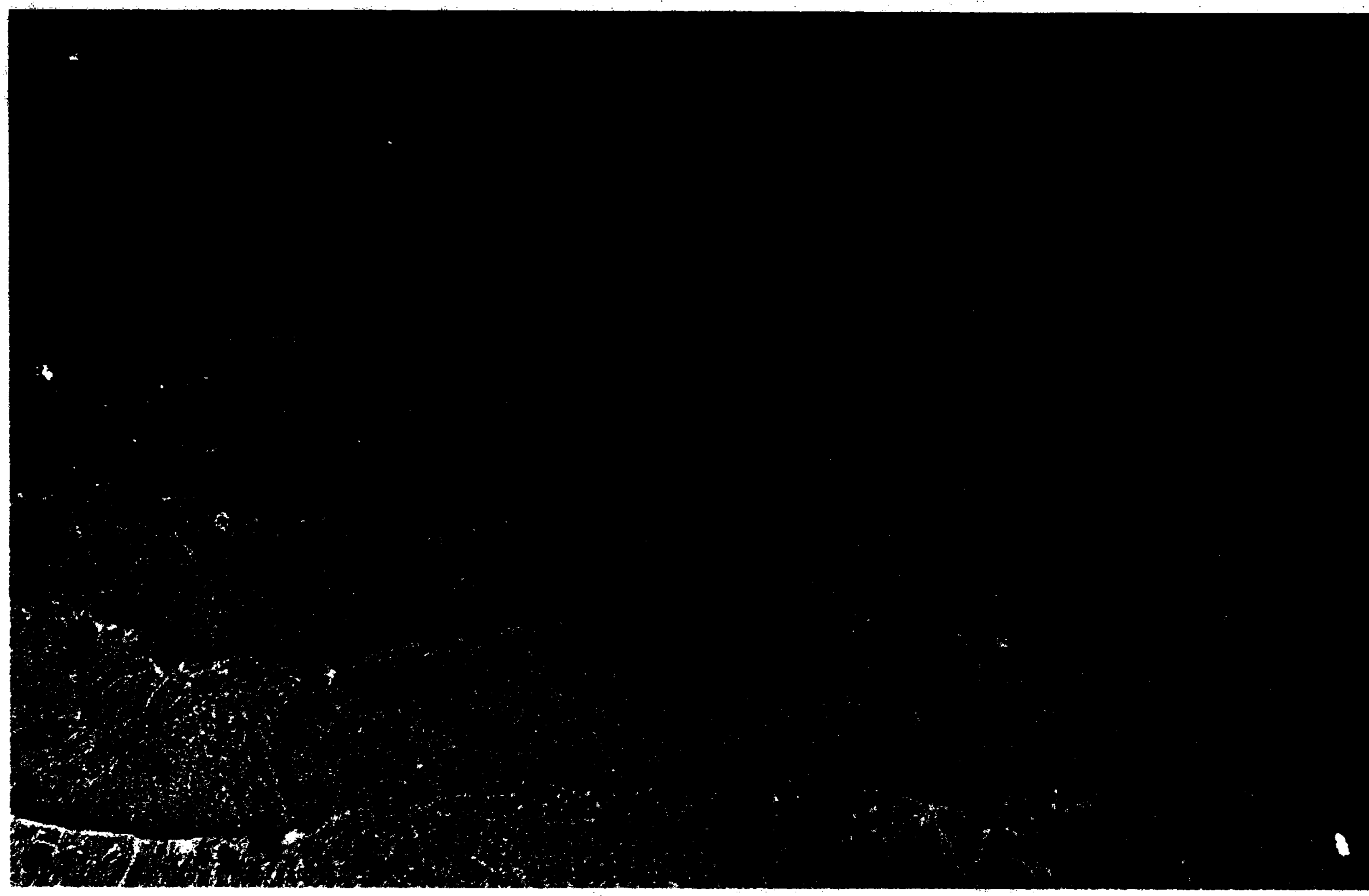


Photo 13. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.6-sec, 10.4-ft waves from 357 deg; +4.4 ft swl

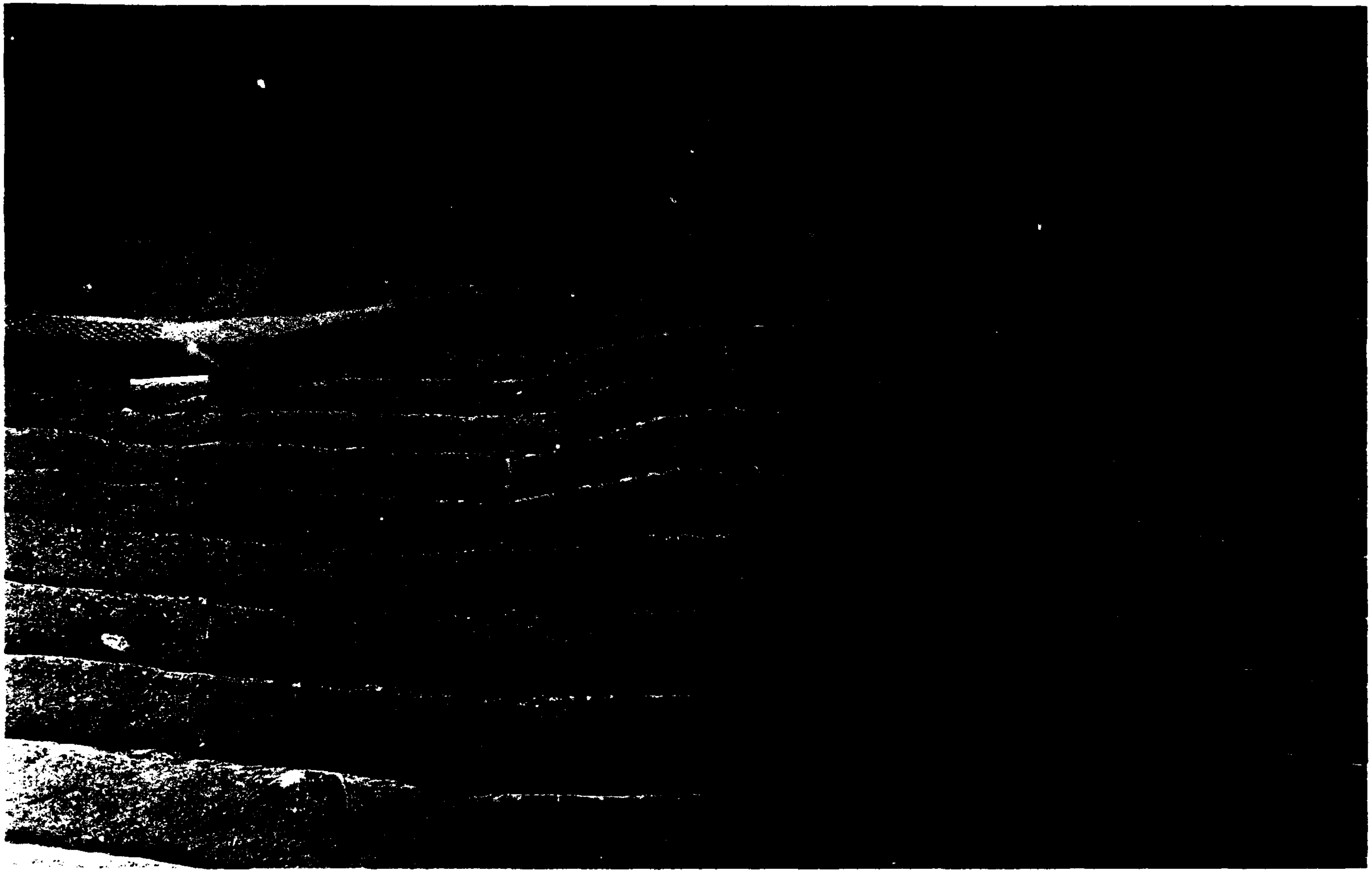


Photo 14. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 5.5-sec, 4.4-ft waves from 19 deg; +0.9 ft swl

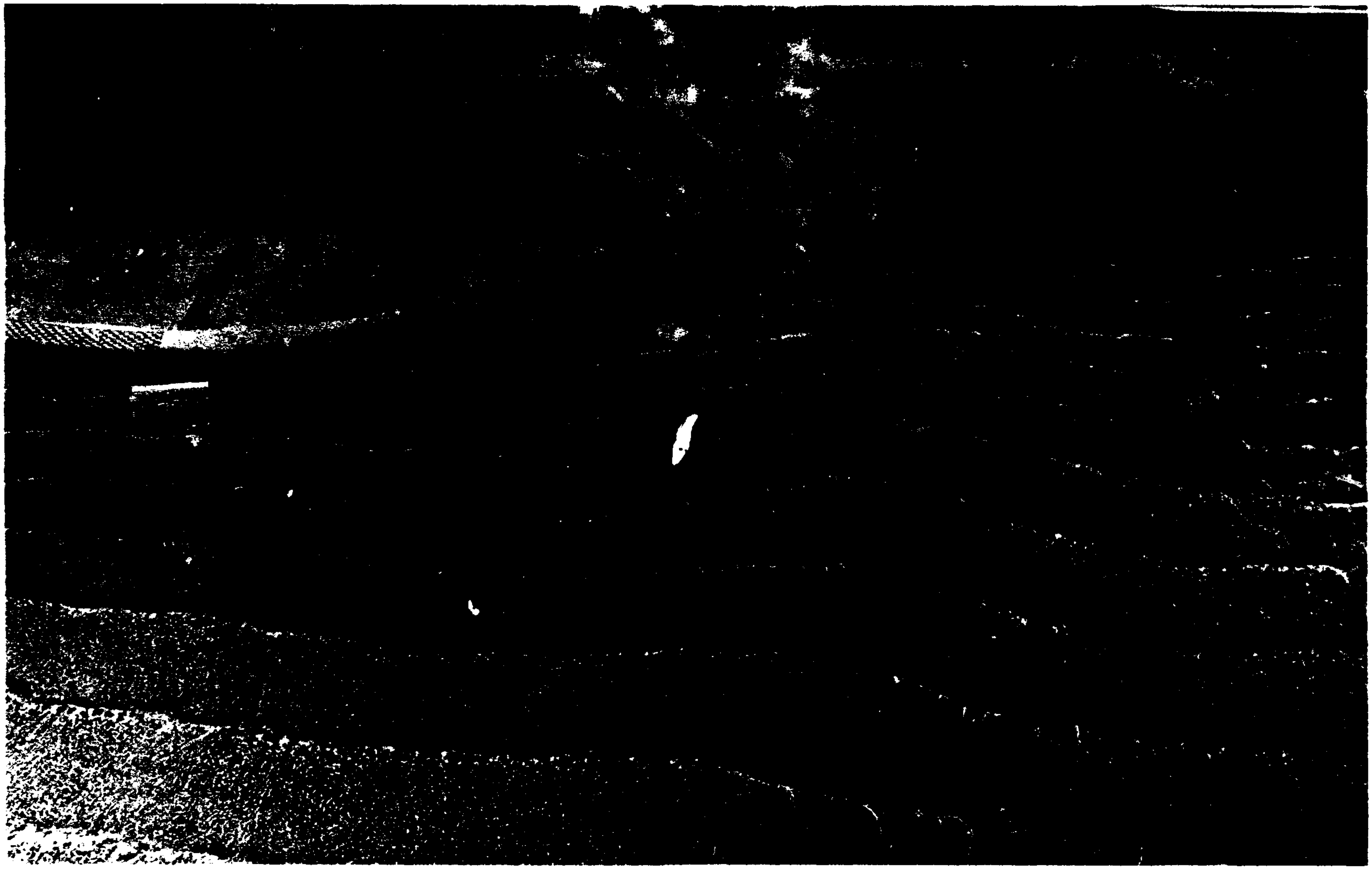


Photo 15. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 6.2-sec, 6.3-ft waves from 19 deg; +0.9 ft swl

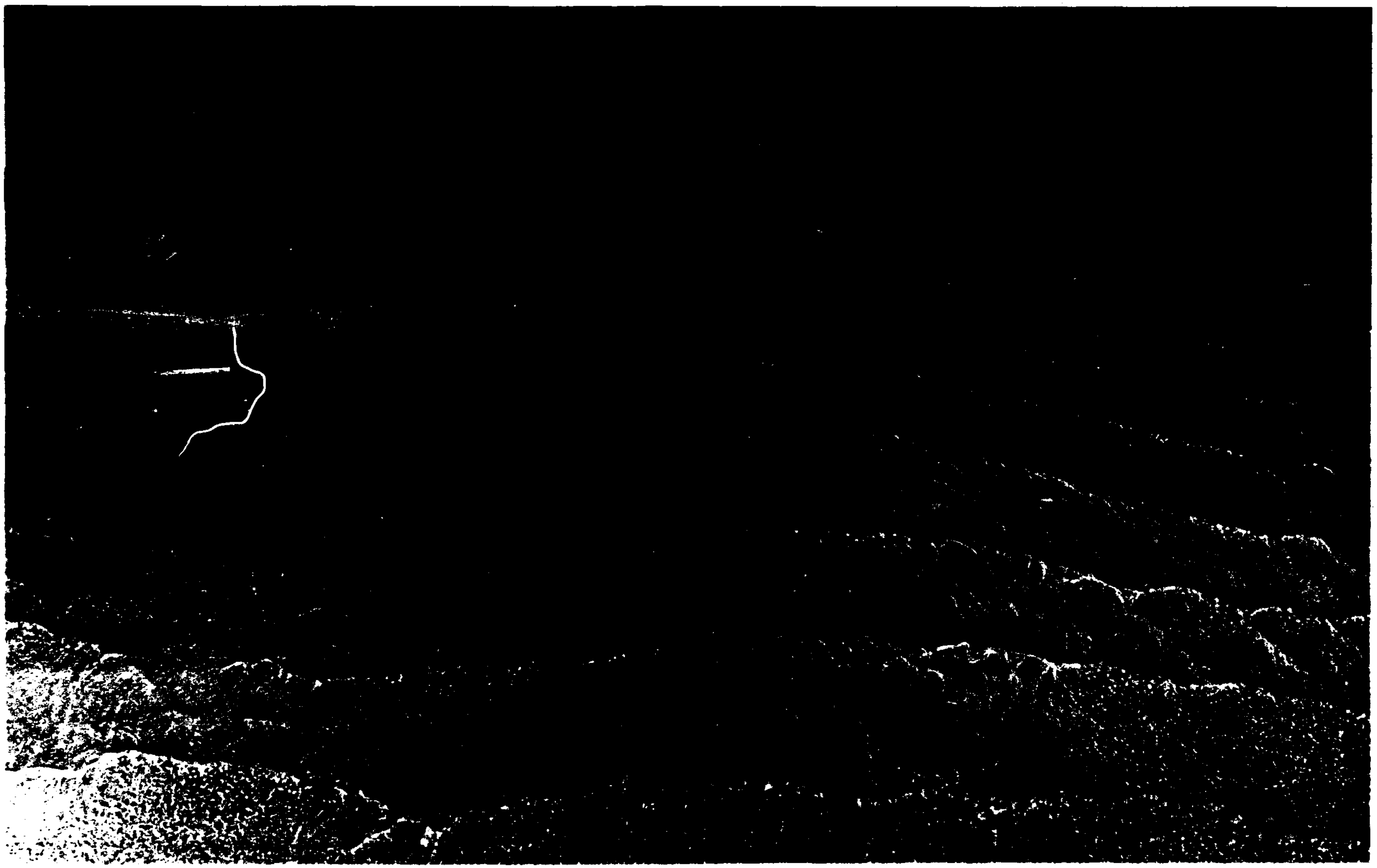


Photo 16. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.1-sec, 9.1-ft waves from 19 deg; +0.9 ft swl

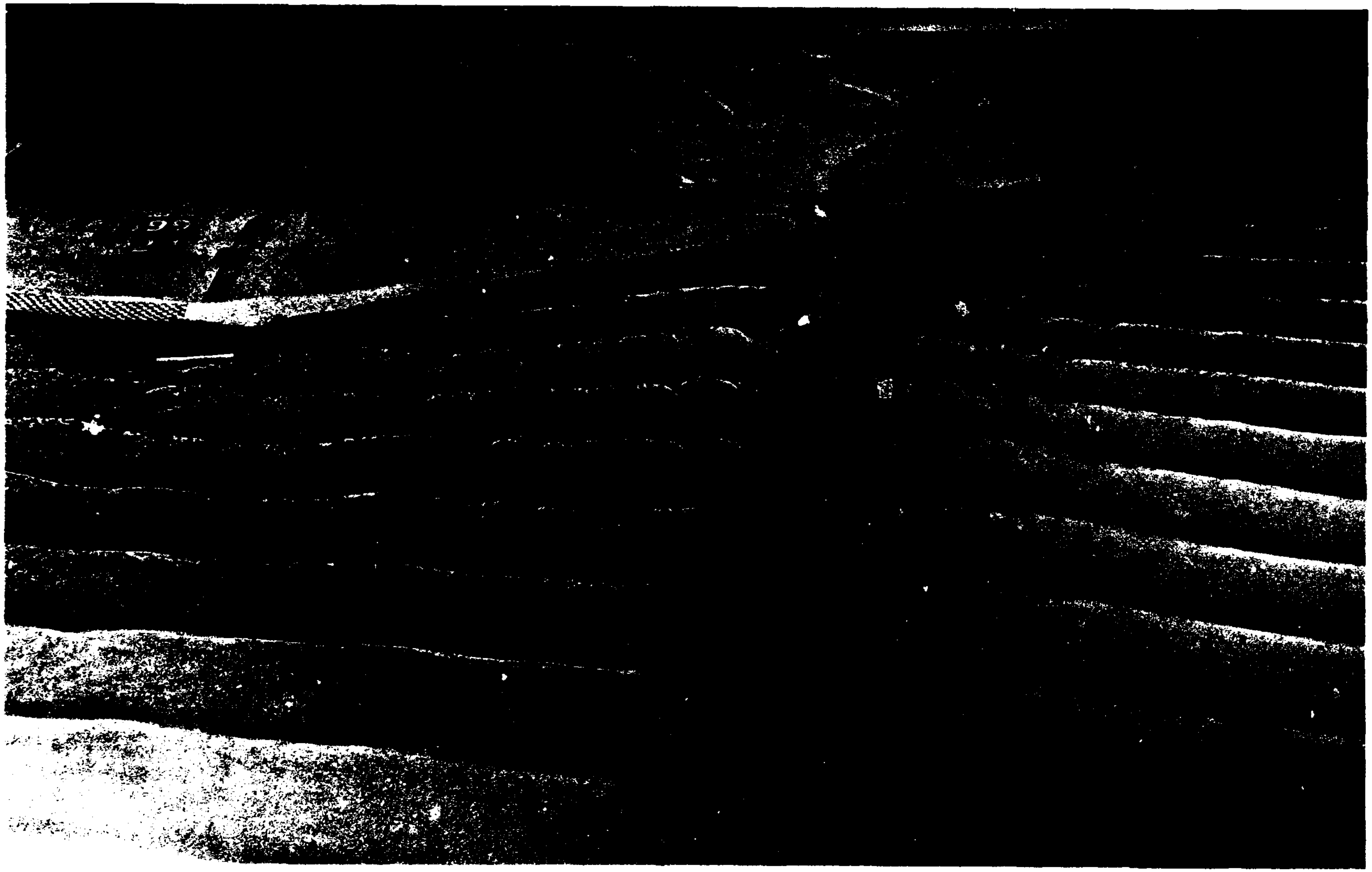
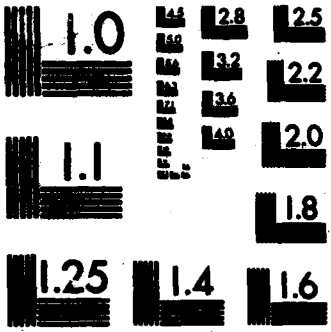


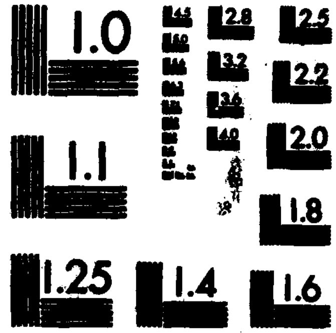
Photo 17. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 5.5-sec, 4.4-ft waves from 19 deg; +4.0 ft swl

AD-A120 823 DESIGN FOR WAVE PROTECTION AND PREVENTION OF SHOALING GENEVA-ON-THE-LAKE..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. R R BOTTIN 2/3

UNCLASSIFIED AUG 82 WES/TR/HL-82-17 F/G 13/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
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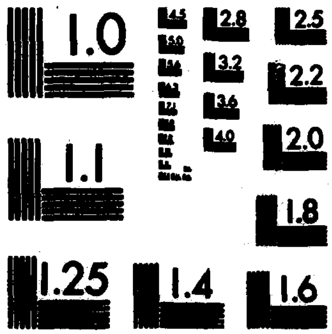

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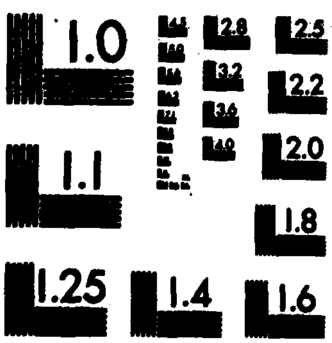

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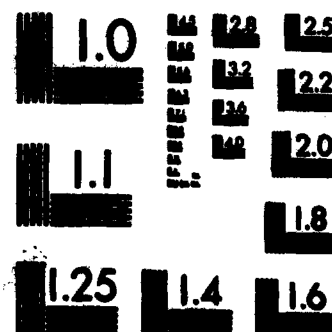


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

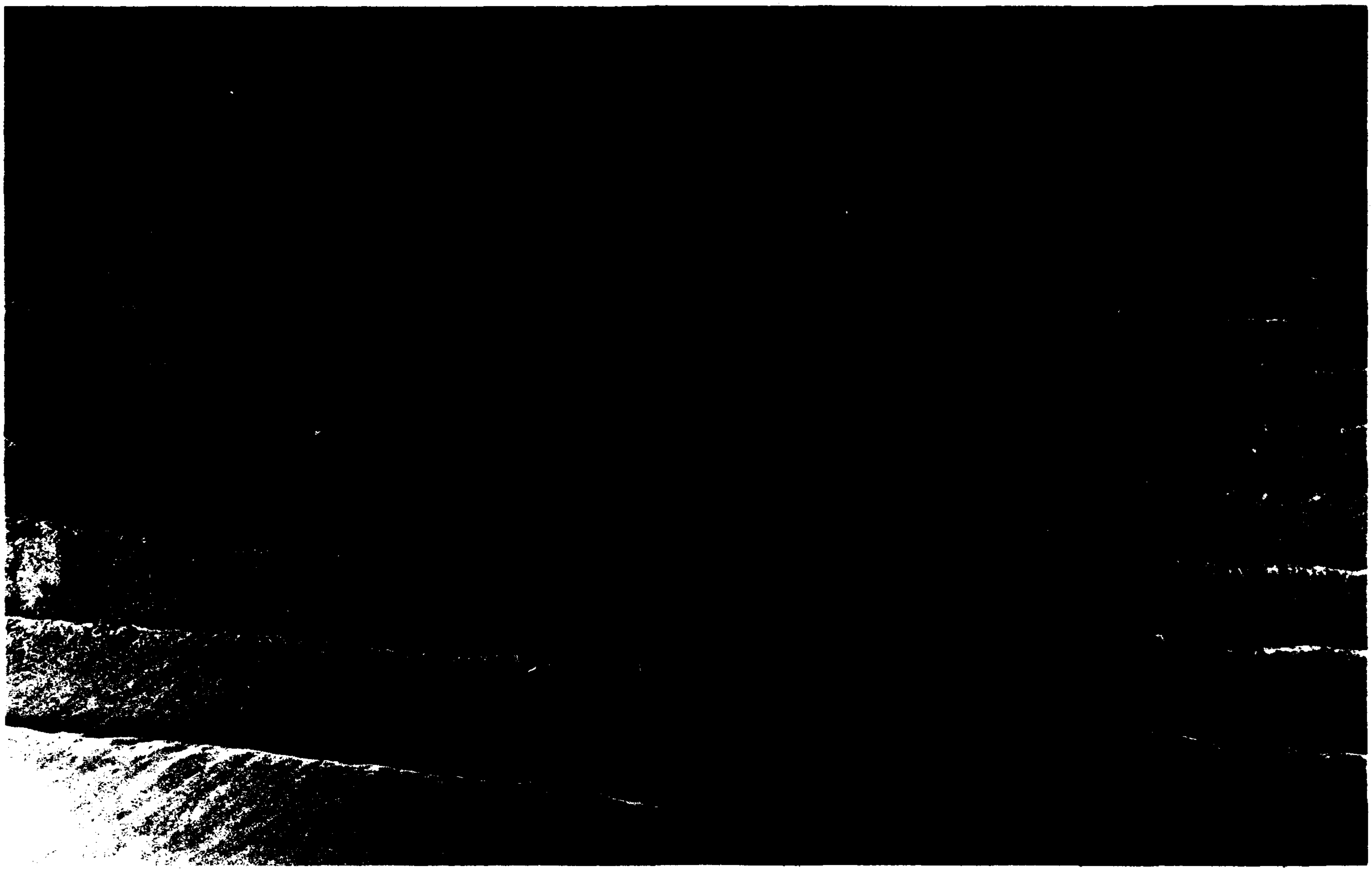


Photo 18. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 6.2-sec, 6.3-ft waves from 19 deg; +4.0 ft swl

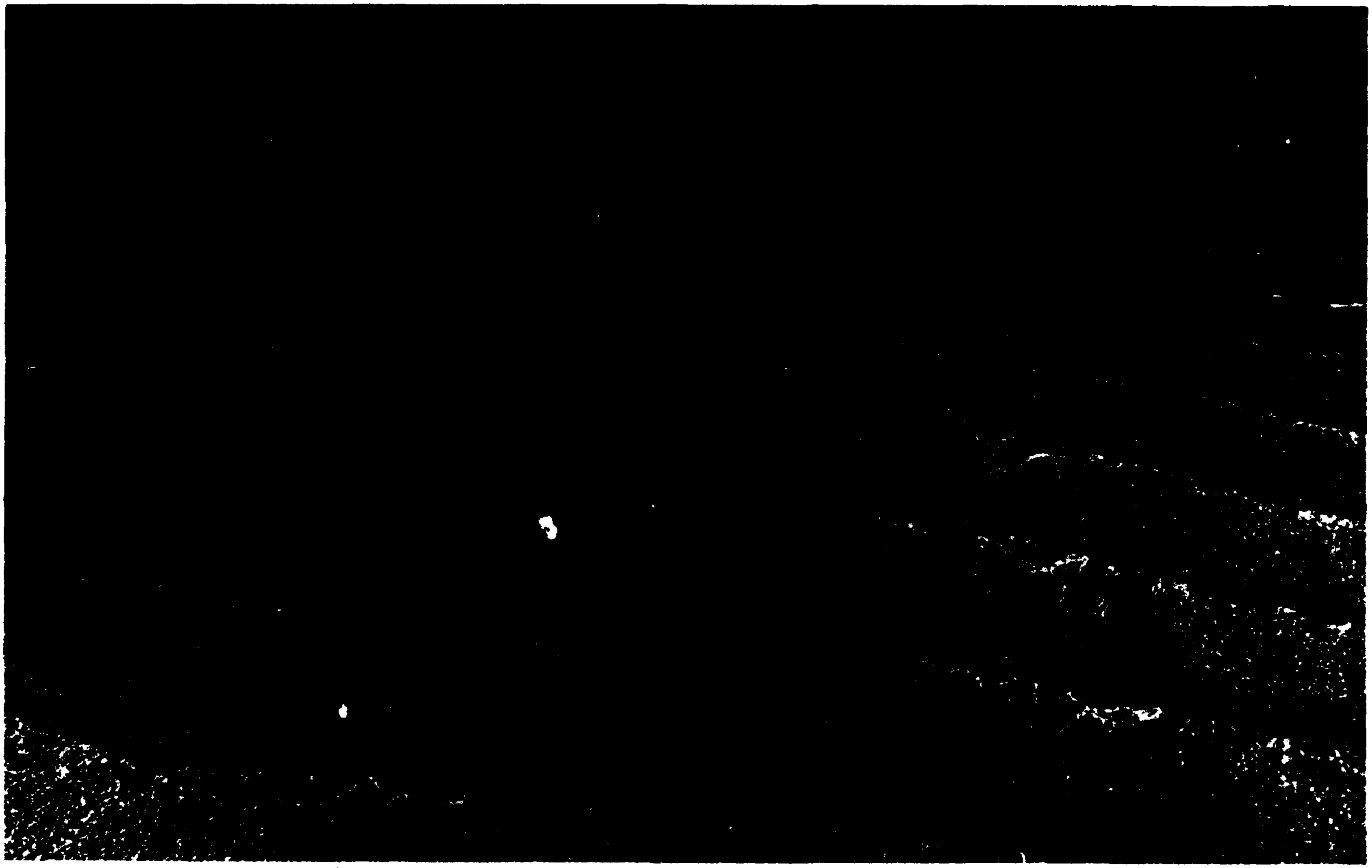


Photo 19. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for existing conditions; 7.1-sec, 9.1-ft waves from 19 deg; +4.0 ft swl

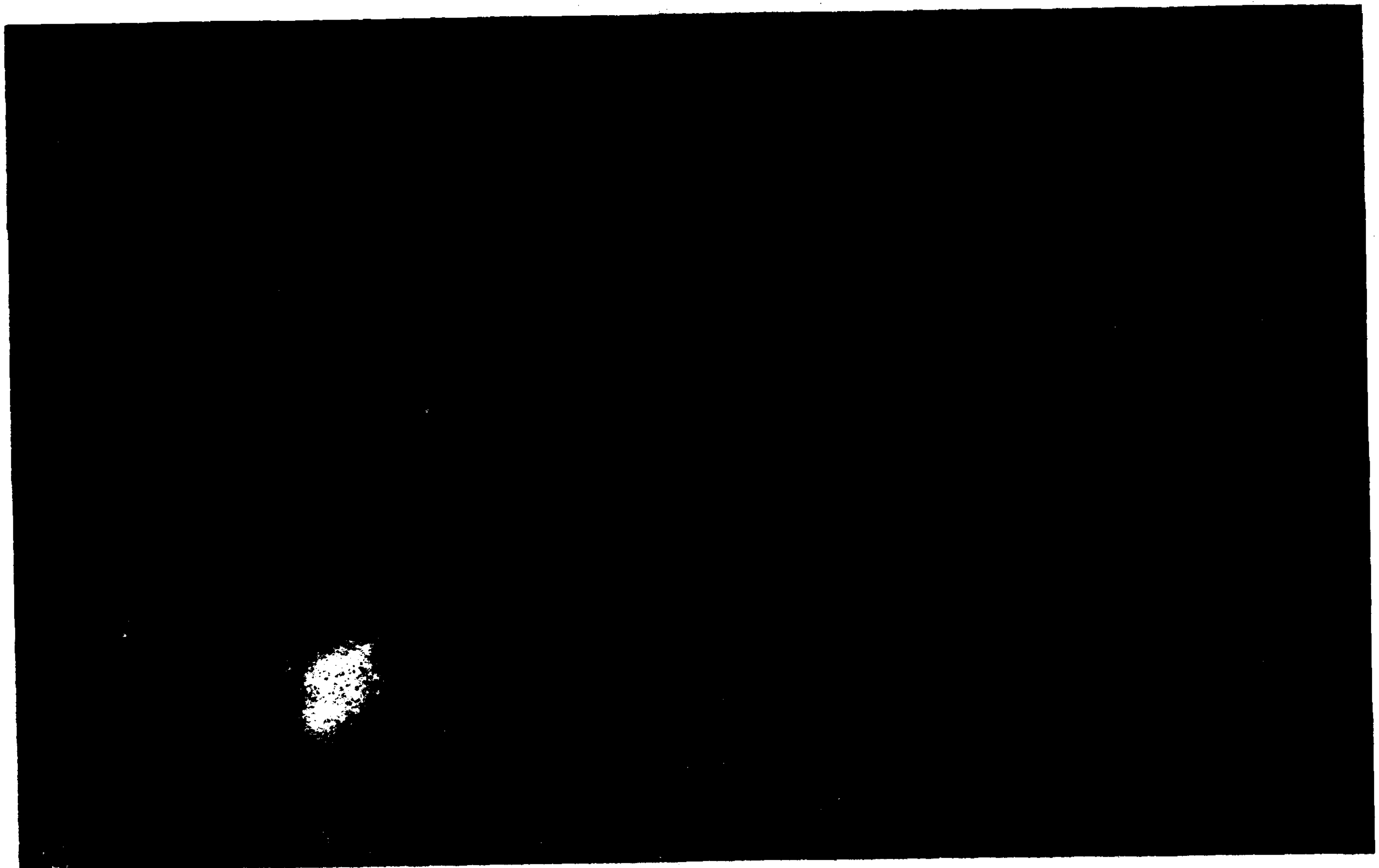


Photo 20. General movement of tracer along the shoreline for existing conditions; 6.6-sec, 5.6-ft waves from 287 deg; +0.9 ft swl

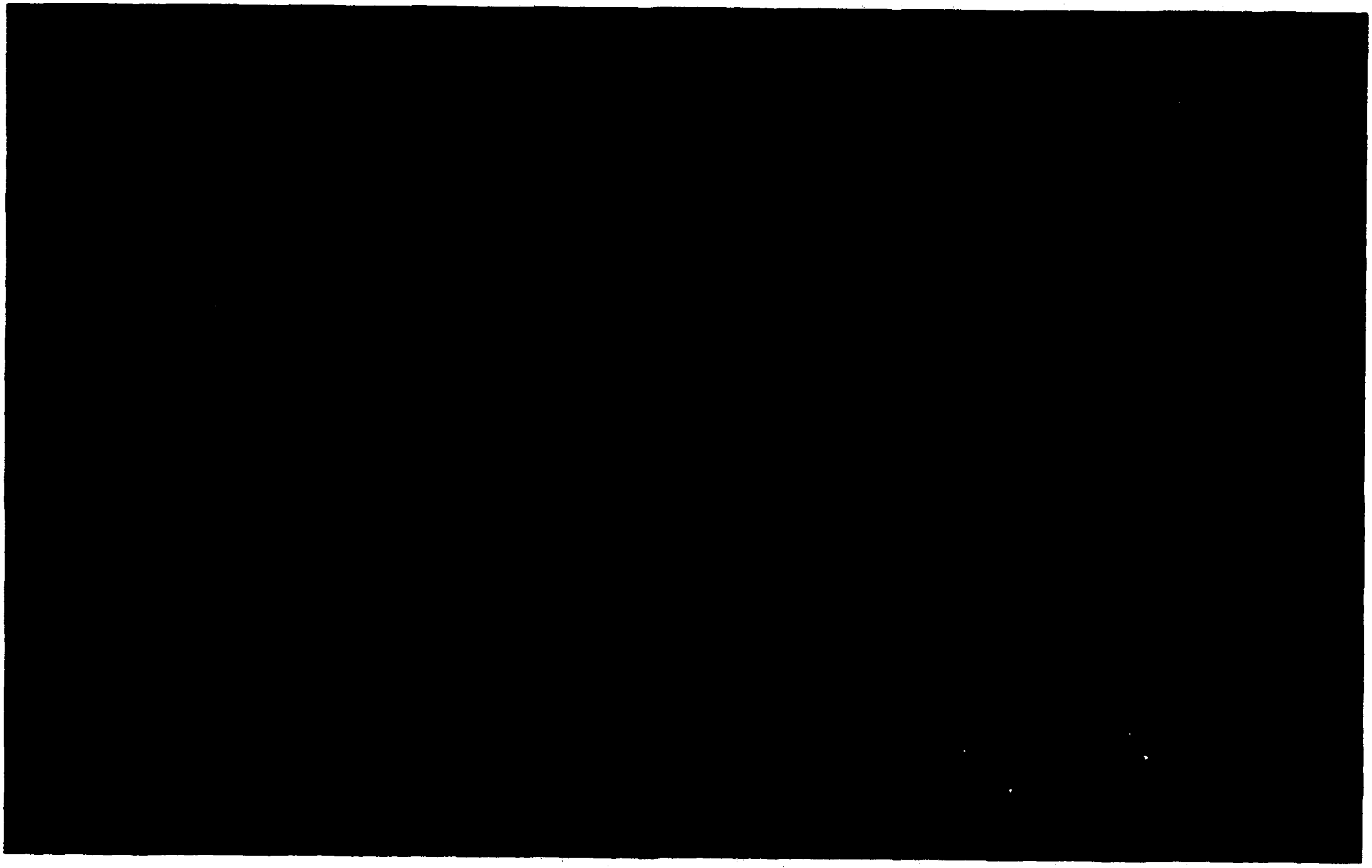


Photo 21. General movement of tracer along the shoreline for existing conditions; 9-sec, 10.9-ft waves from 287 deg; +0.9 ft swl

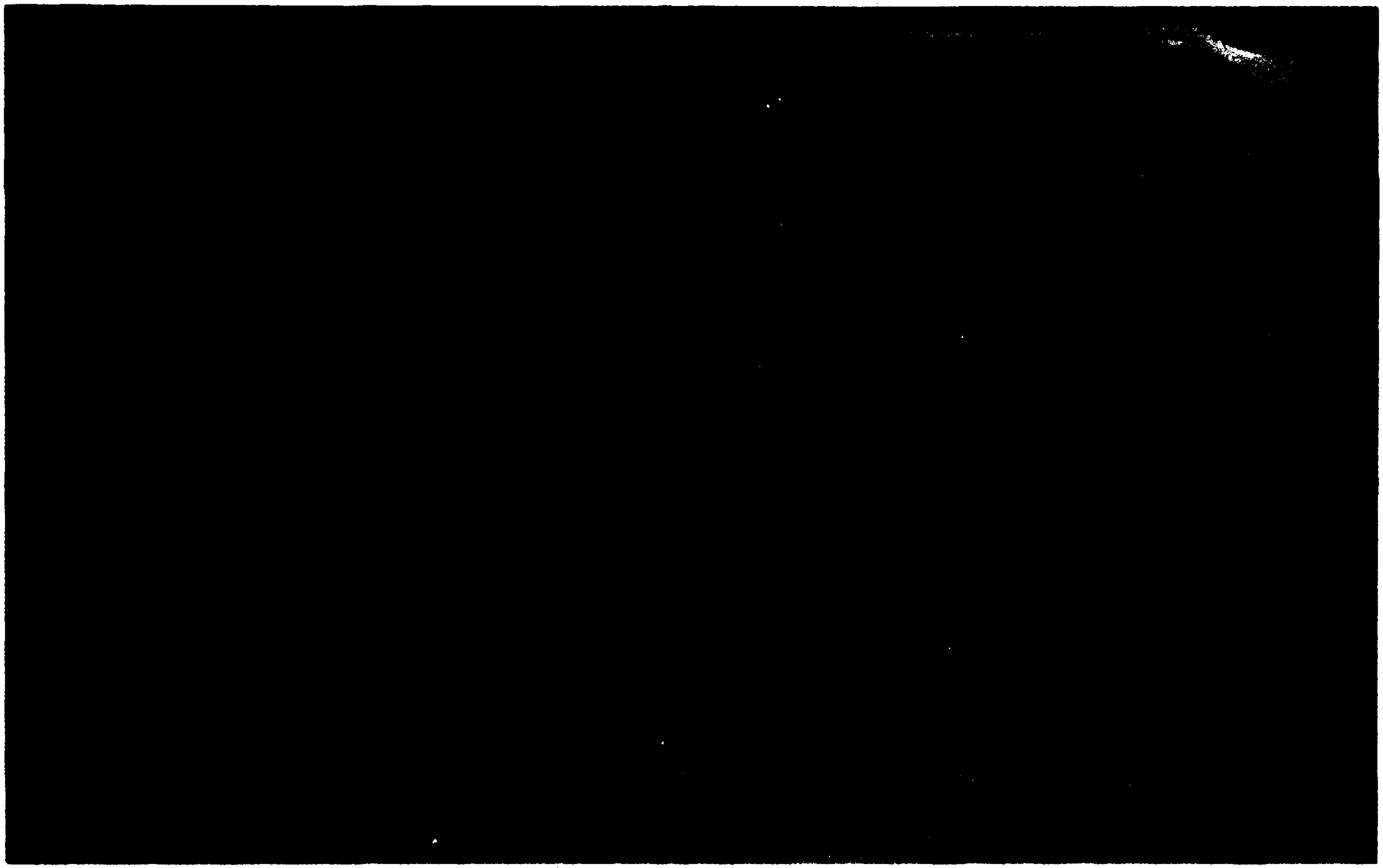


Photo 22. General movement of tracer along the shoreline for existing conditions; 6.6-sec, 5.6-ft waves from 287 deg; +4.0 ft swl

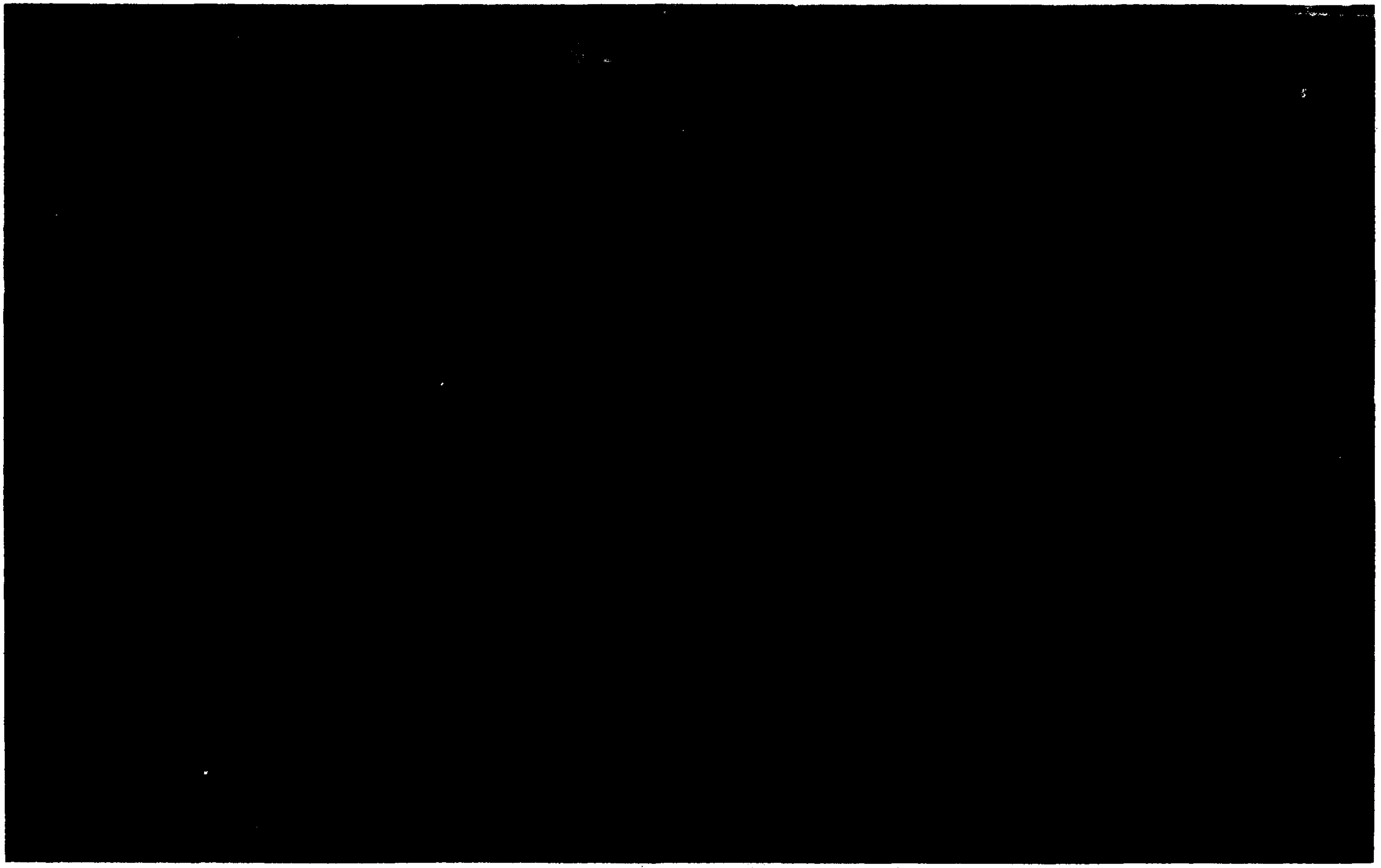


Photo 23. General movement of tracer along the shoreline for existing conditions; 9-sec, 10.9-ft waves from 287 deg; +4.0 ft swl

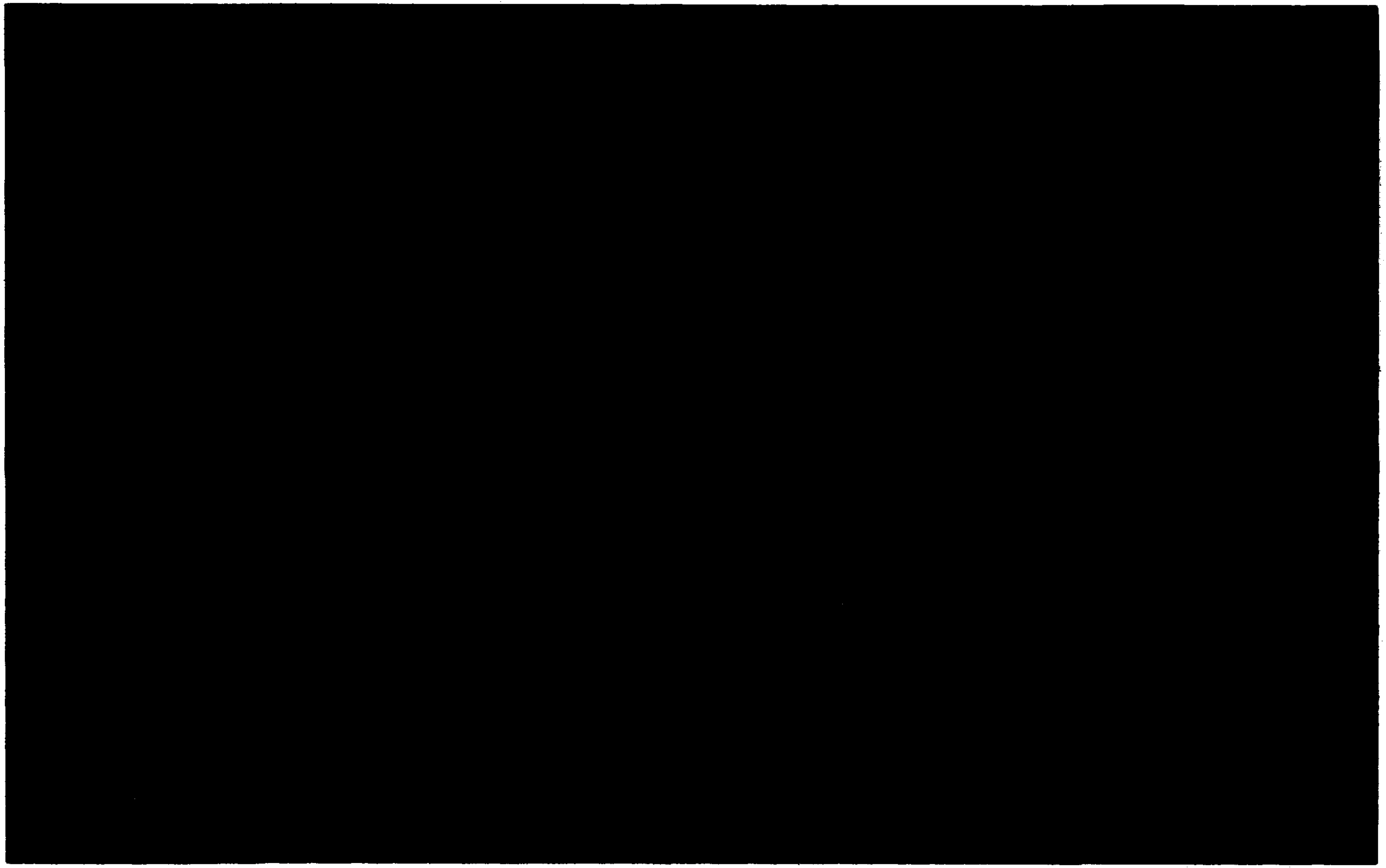


Photo 24. General movement of tracer along the shoreline for existing conditions; 8.8-sec, 10.4-ft waves from 287 deg; +4.4 ft swl

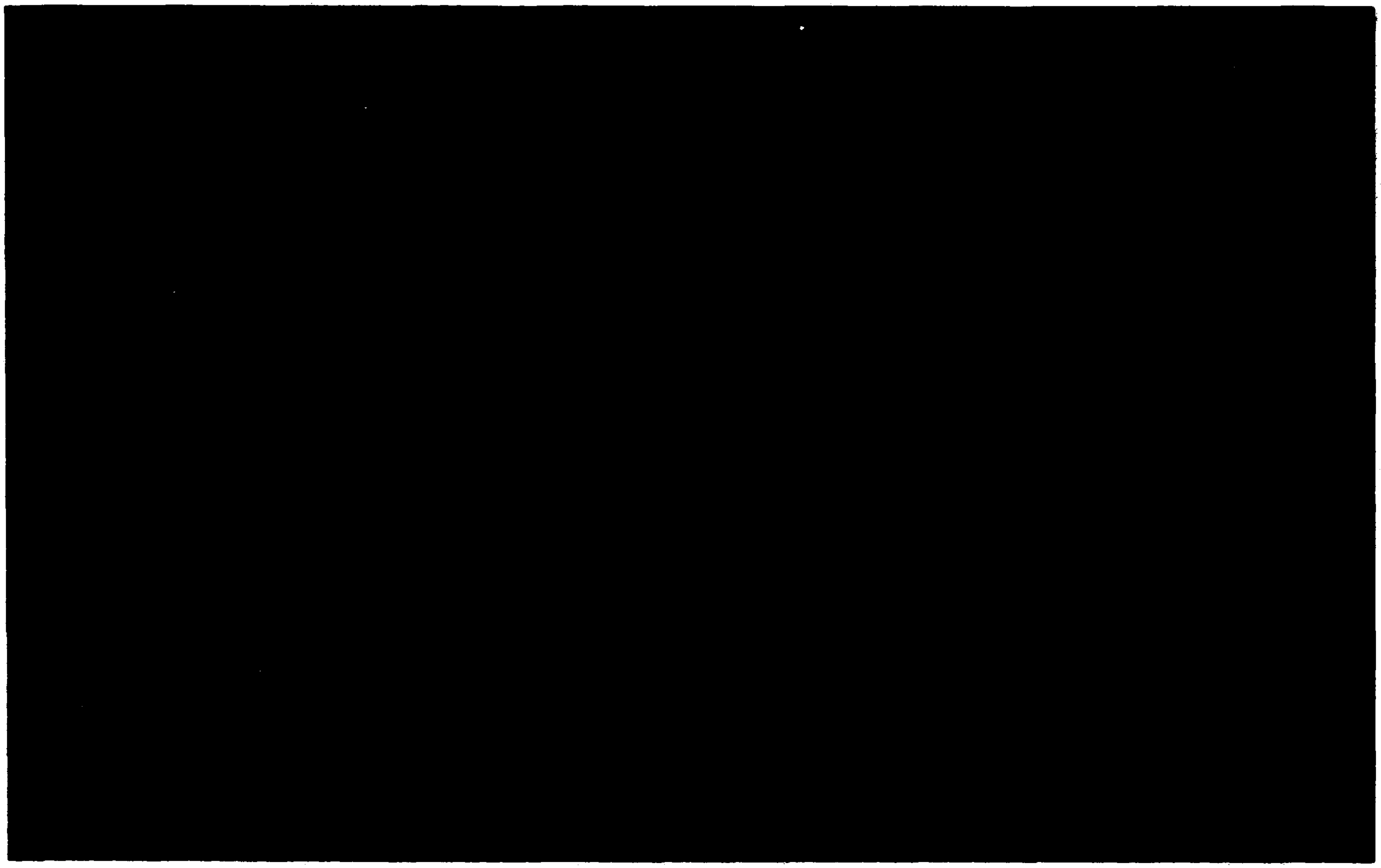


Photo 25. General movement of tracer along the shoreline for existing conditions; 5.8-sec, 4.6-ft waves from 357 deg; +0.9 ft swl

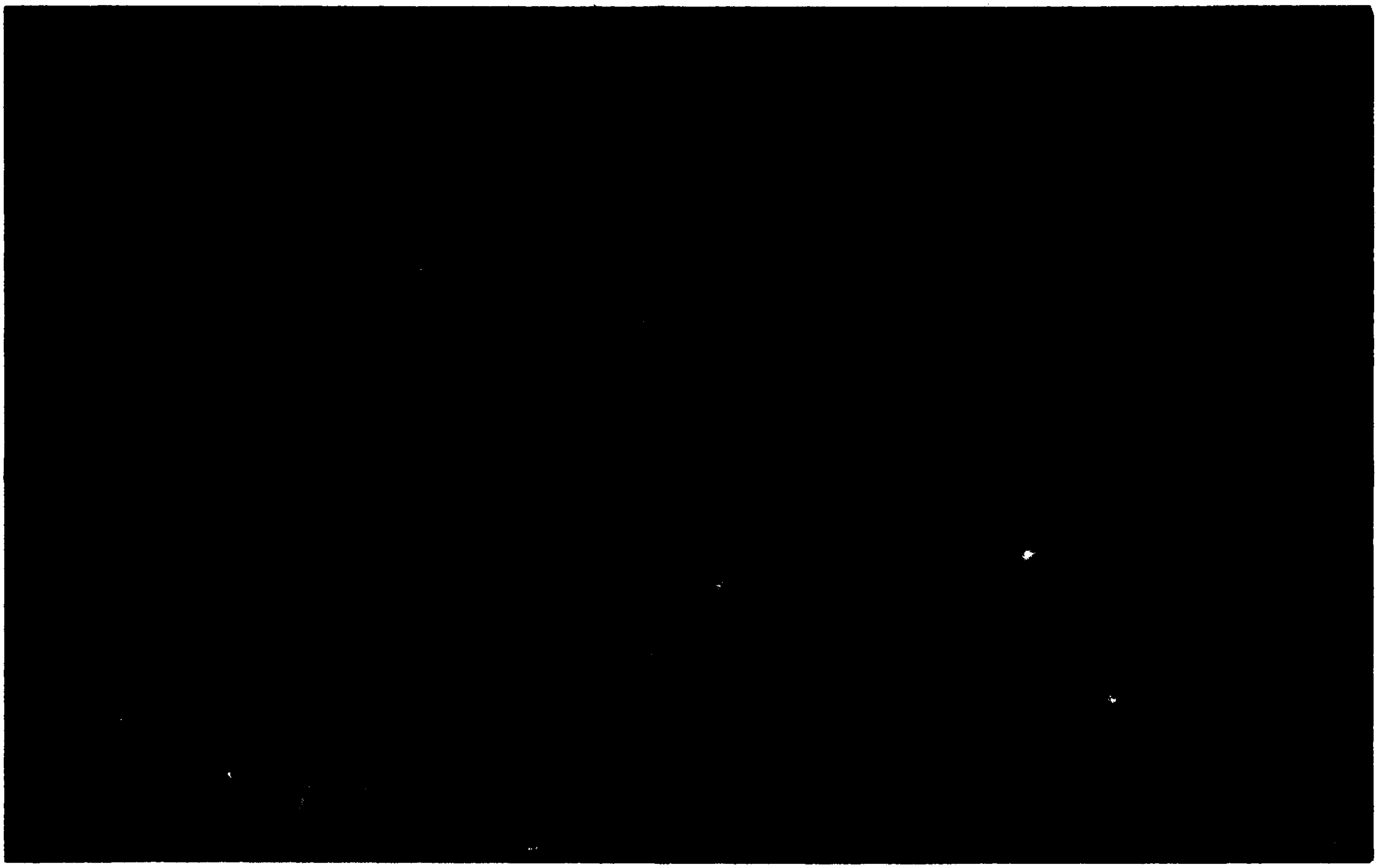


Photo 26. General movement of tracer along the shoreline for existing conditions; 7.8-sec, 10.9-ft waves from 357 deg; +0.9 ft swl

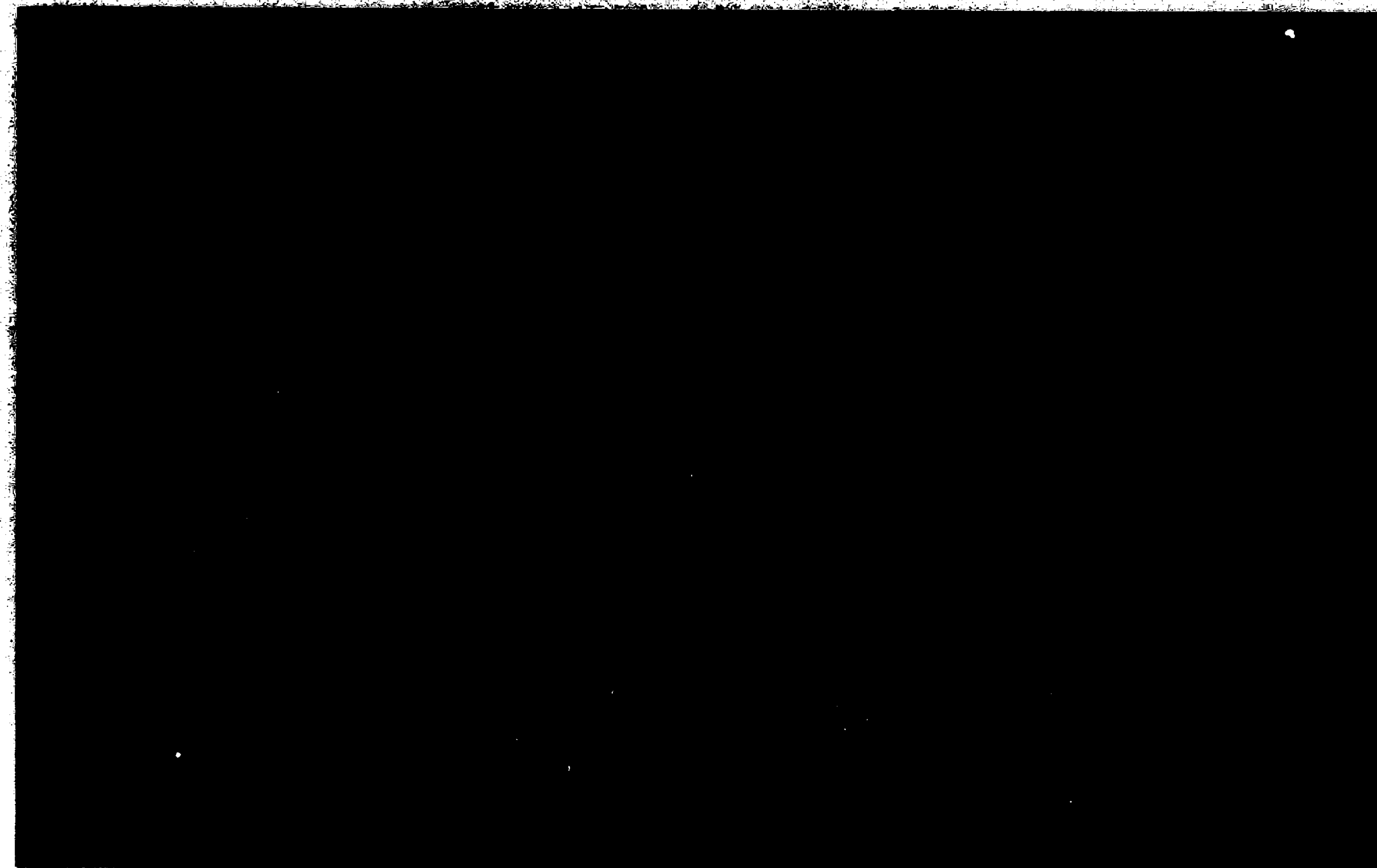


Photo 27. General movement of tracer along the shoreline for existing conditions; 5.8-sec, 4.6-ft waves from 357 deg; +4.0 ft swl

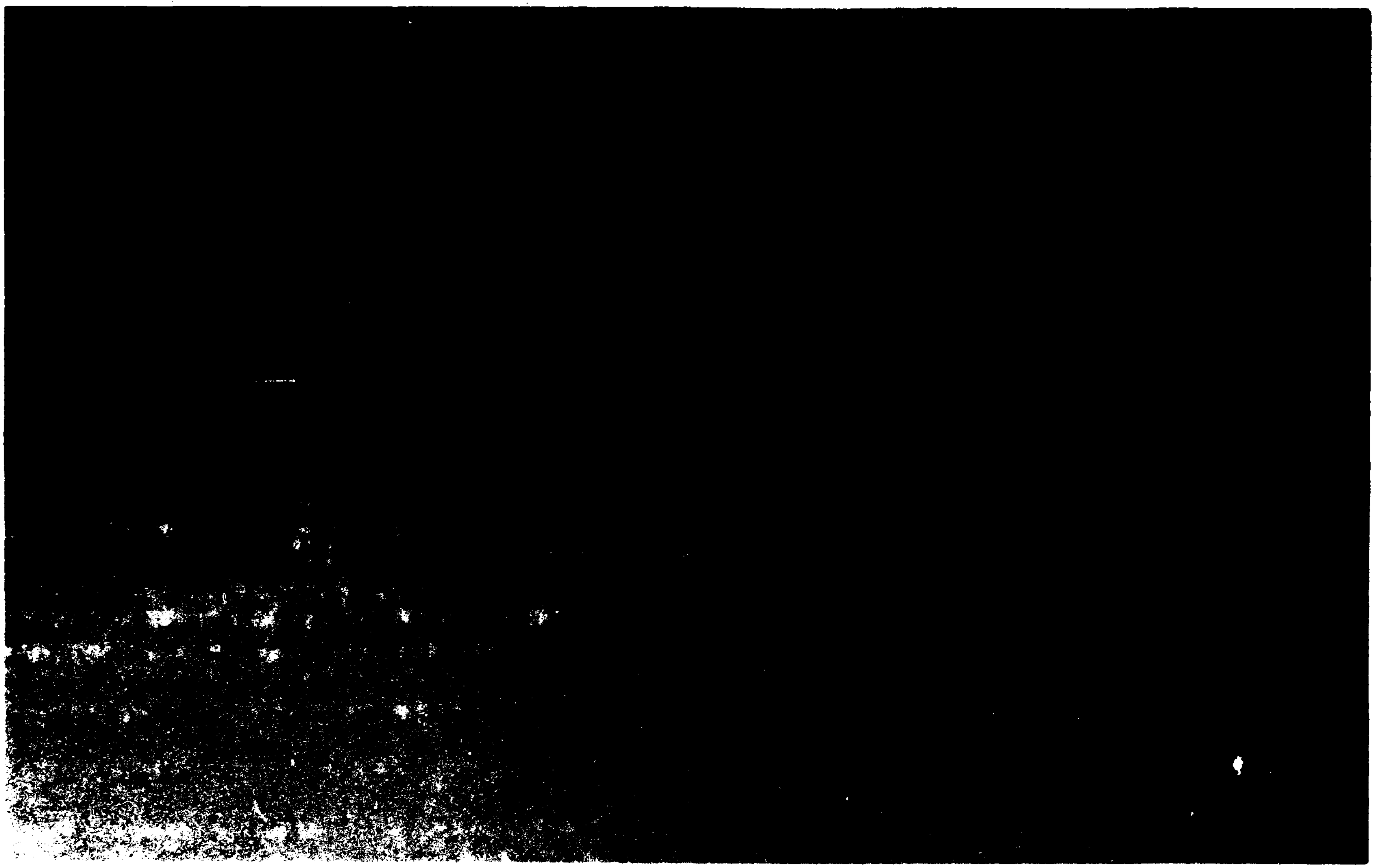


Photo 28. General movement of tracer along the shoreline for existing conditions; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

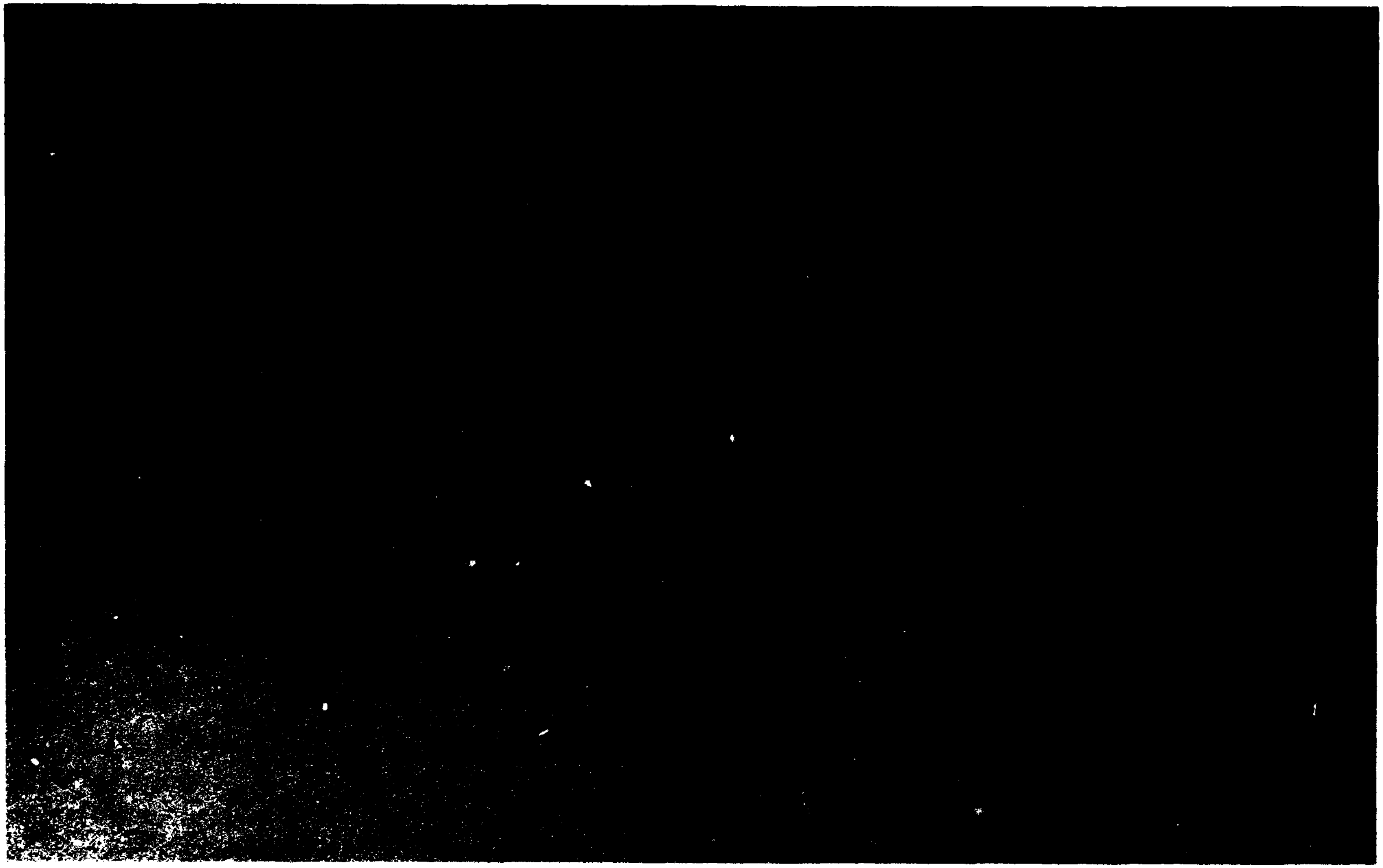


Photo 29. General movement of tracer along the shoreline for existing conditions; 7.6-sec, 10.4-ft waves from 357 deg; +4.4 ft swl

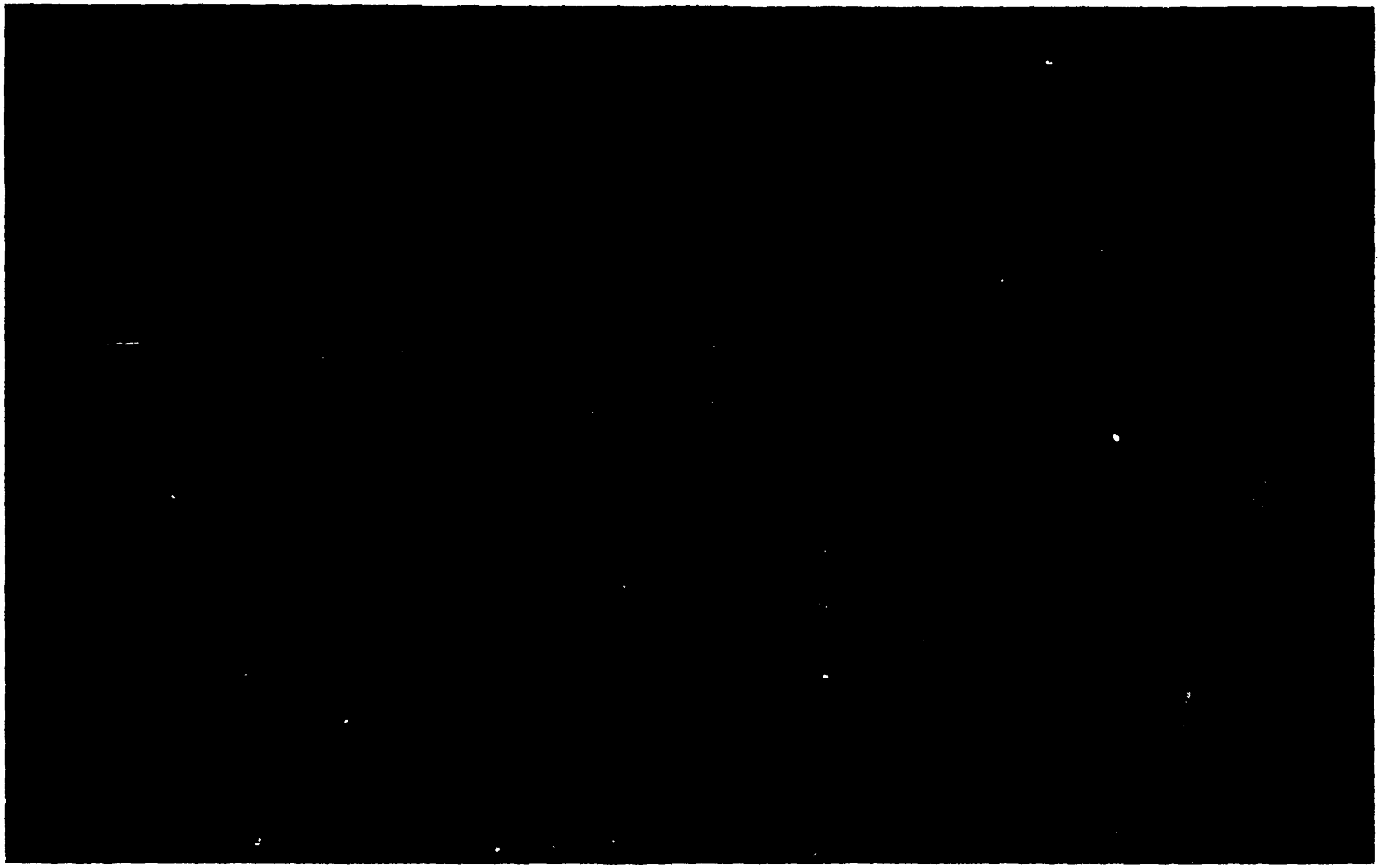


Photo 30. General movement of tracer material along the shoreline for existing conditions; 5.5-sec, 6.3-ft waves from 19 deg; +0.9 ft swl

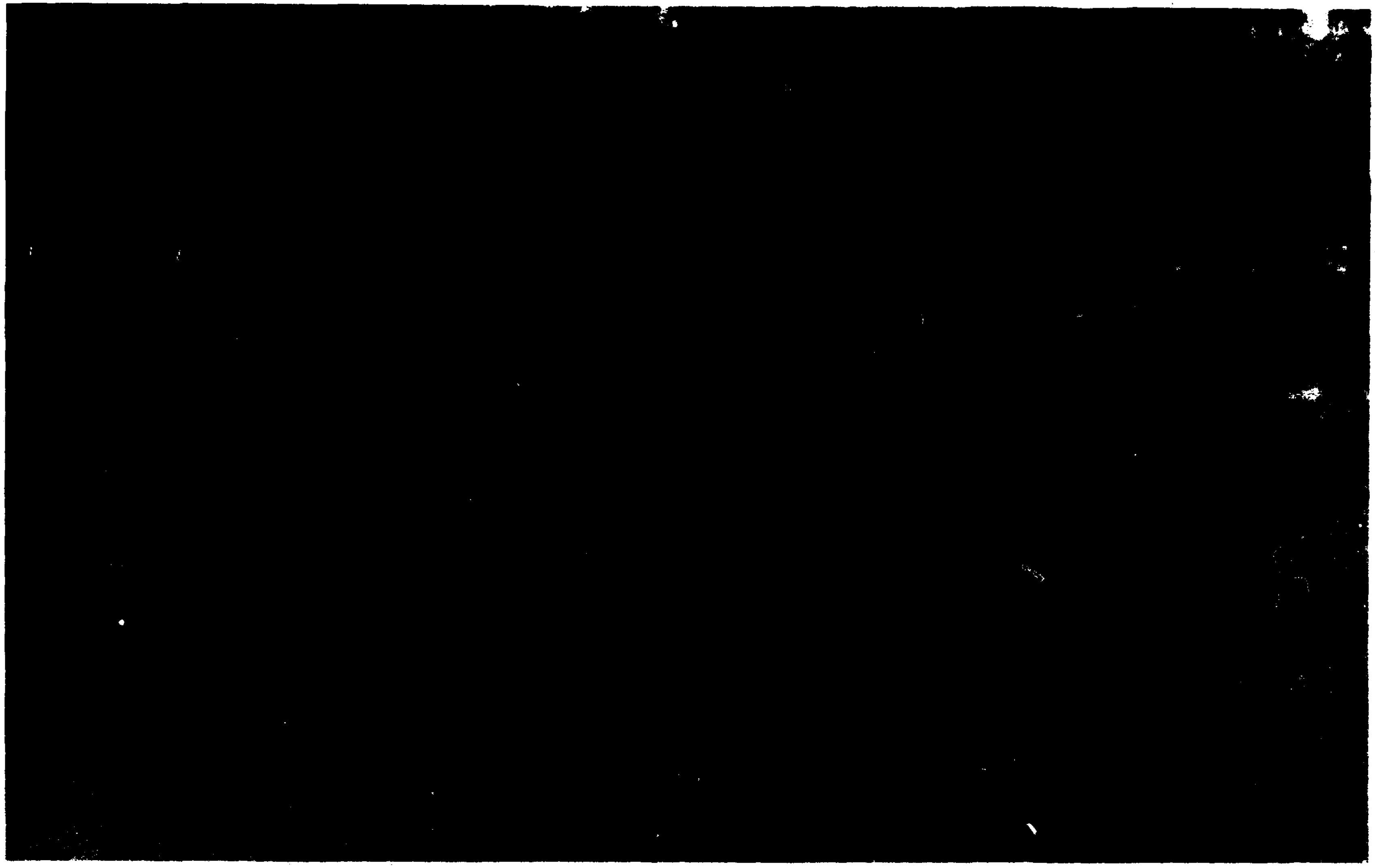


Photo 31. General movement of tracer material along the shoreline for existing conditions; 7.1-sec, 9.1-ft waves from 19 deg; +0.9 ft swl

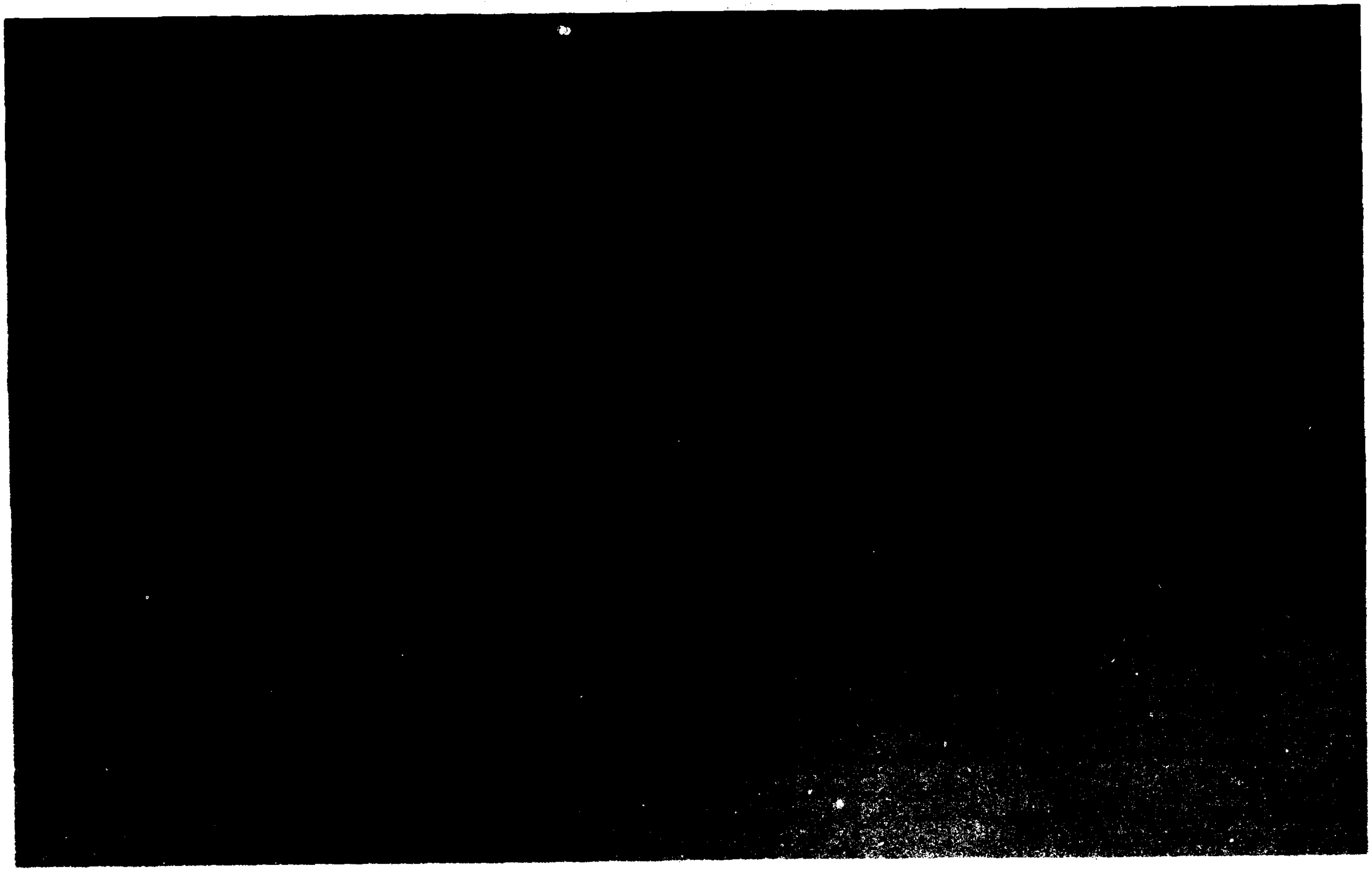


Photo 32. General movement of tracer material along the shoreline for existing conditions; 5.5-sec, 6.3-ft waves from 19 deg; +4.0 ft swl

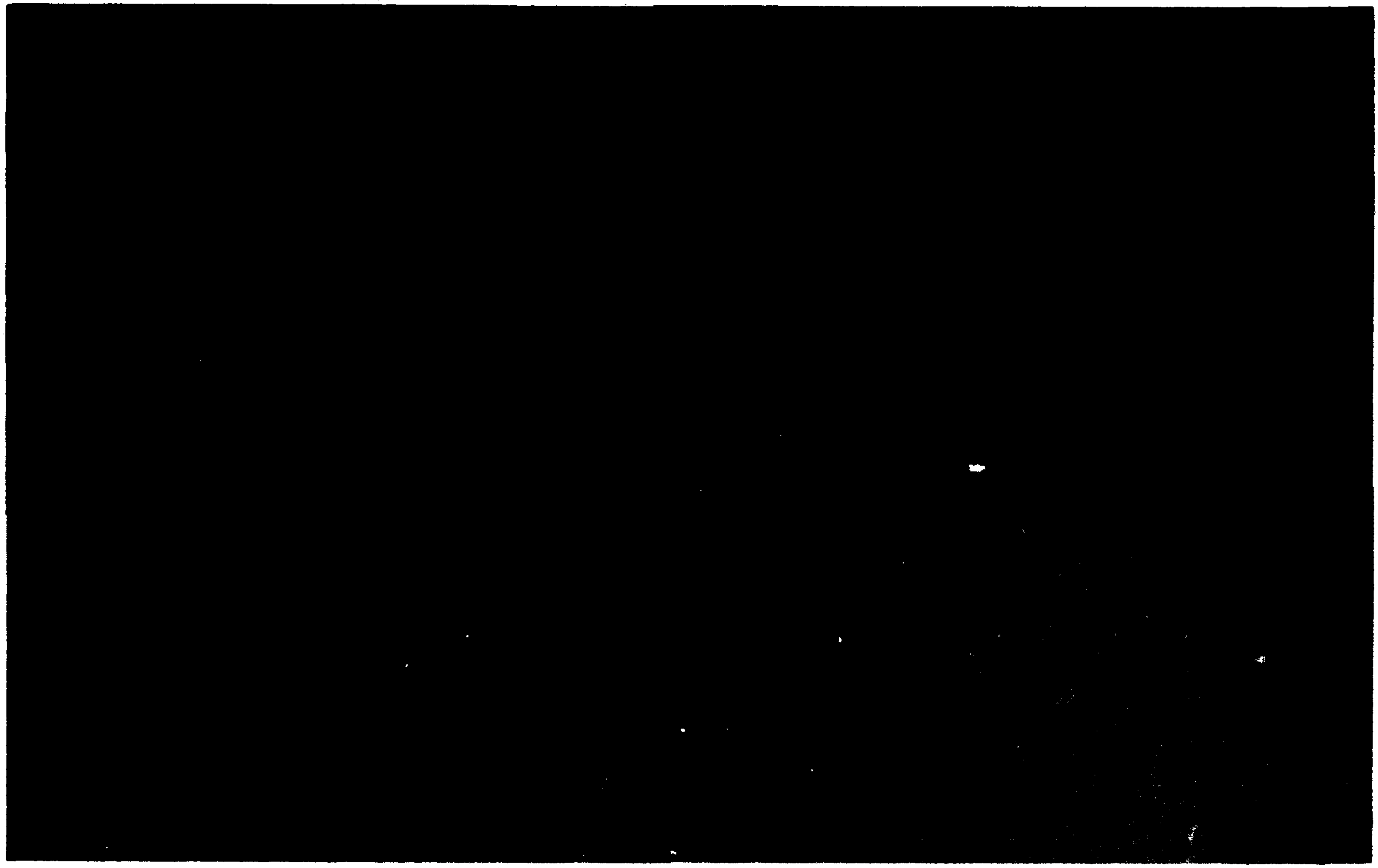


Photo 33. General movement of tracer material along the shoreline for existing conditions; 7.1-sec, 9.1-ft waves from 19 deg; +4.0 ft swl

Photo 34. Typical wave and tracer patterns for Base Test; 9-sec, 10.9-ft waves from 287 deg; +0.9 ft swl

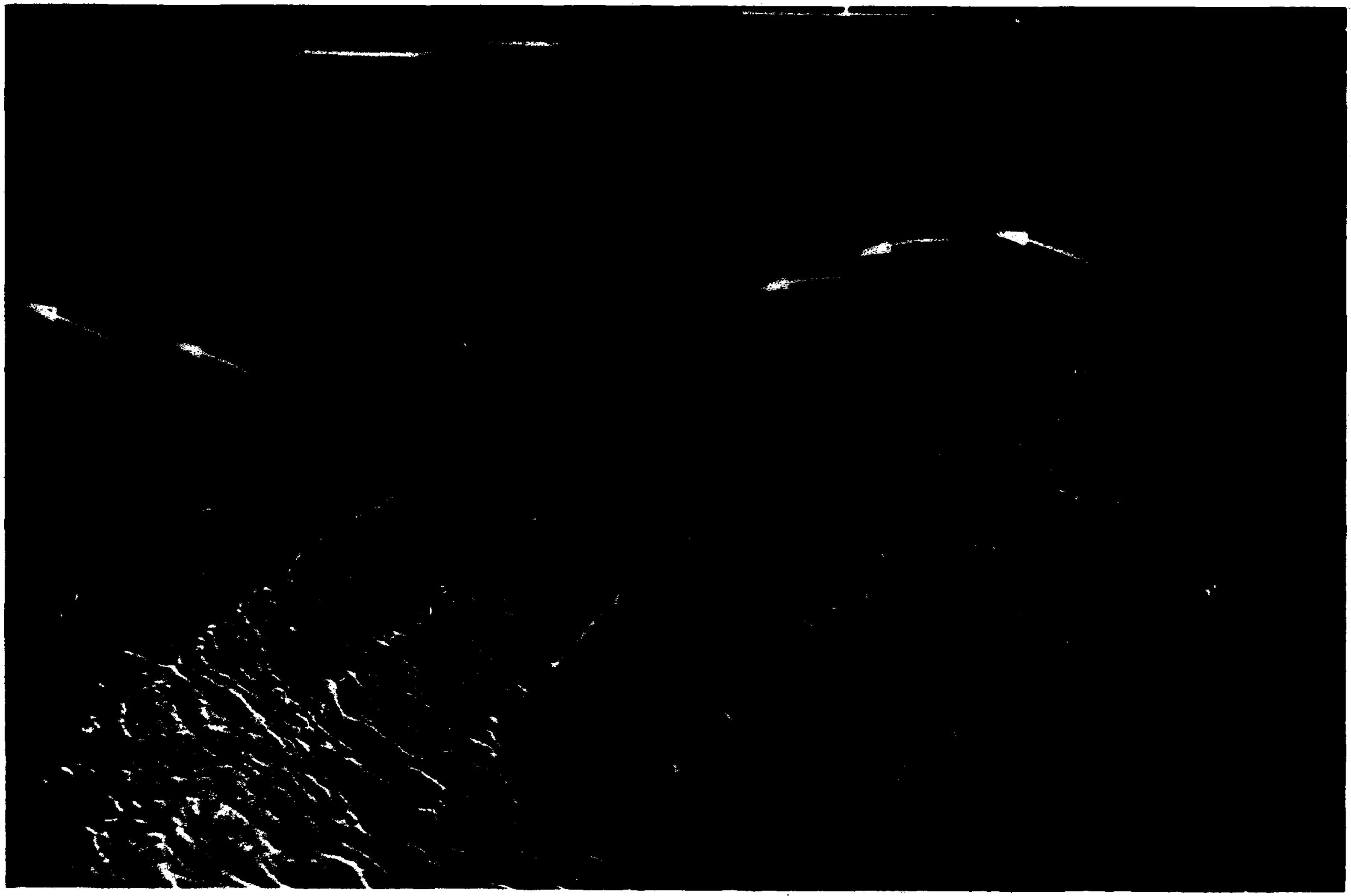


Photo 35. Typical wave and tracer patterns for Base Test; 6.6-sec, 5.6-ft waves from 287 deg; +4.0 ft swl

Photo 36. Typical wave and tracer patterns for Base Test; 9-sec, 10.9-ft waves from 287 deg; +4.0 ft swl

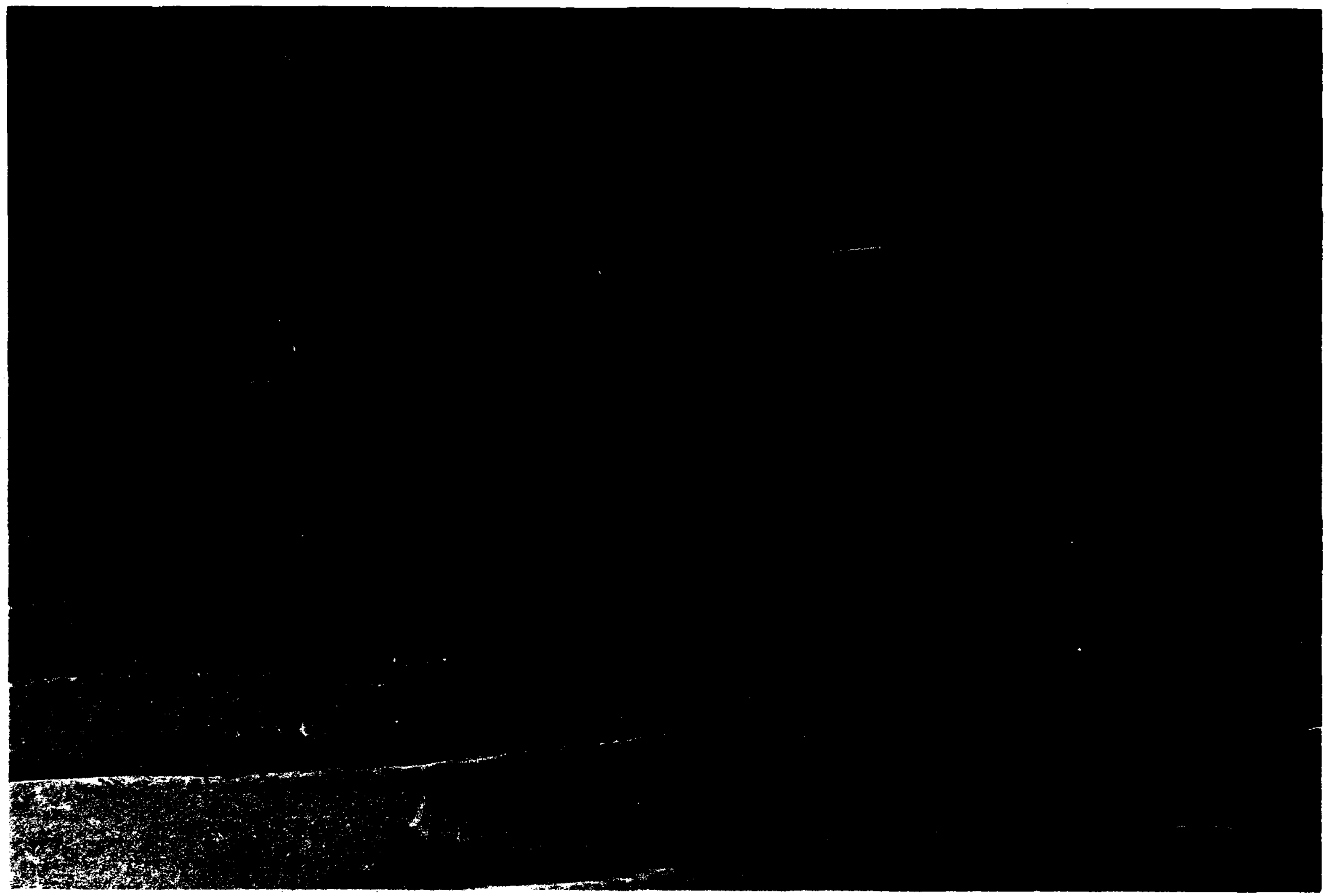


Photo 37. Typical wave and tracer patterns for Base Test; 5.8-sec, 4.6-ft waves from 357 deg; +0.9 ft swl

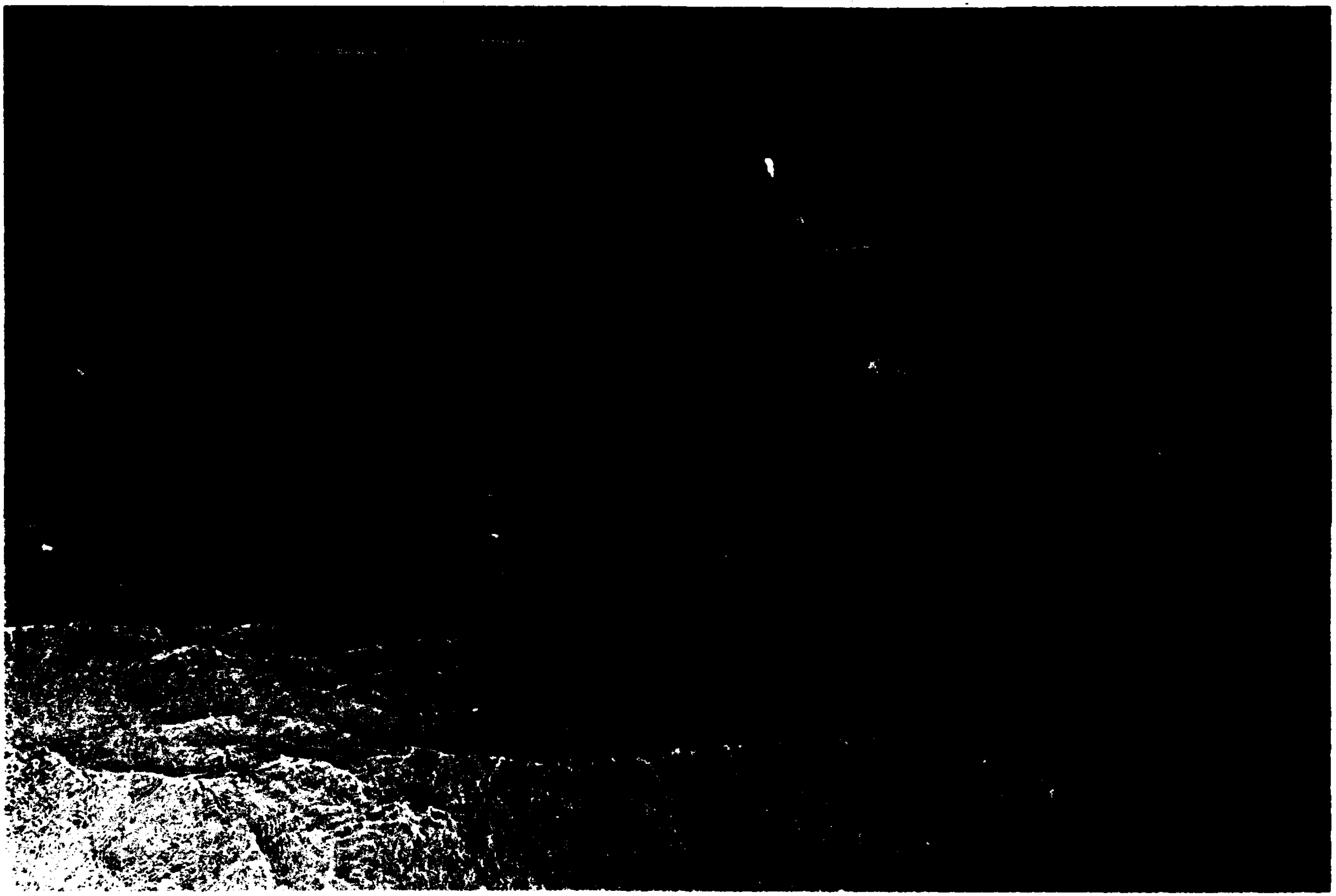


Photo 38. Typical wave and tracer patterns for Base Test; 7.8-sec, 10.9-ft waves from 357 deg; +0.9 ft swl

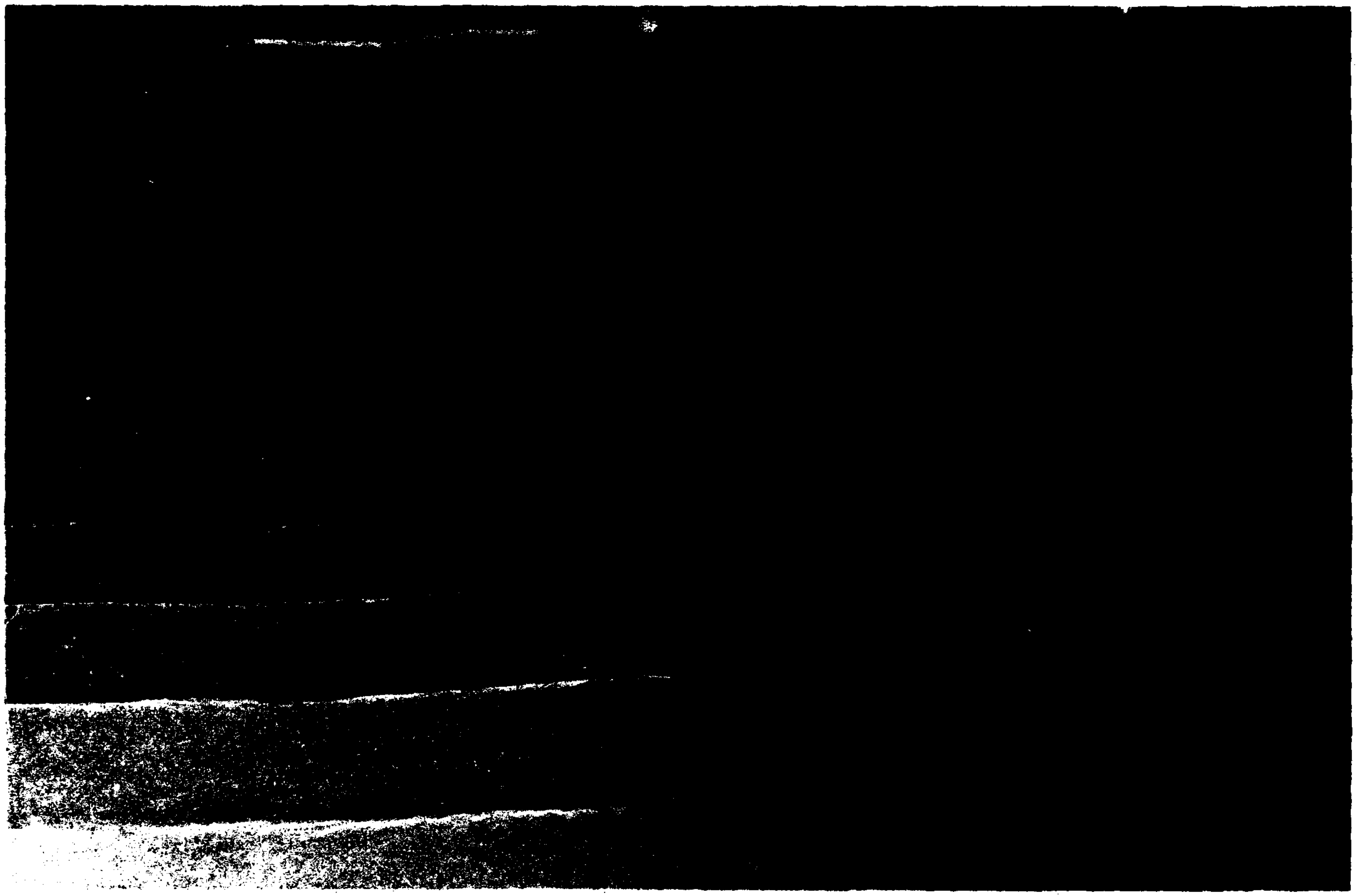


Photo 39. Typical wave and tracer patterns for Base Test; 5.8-sec, 4.6-ft waves from 357 deg; +4.0 ft swl

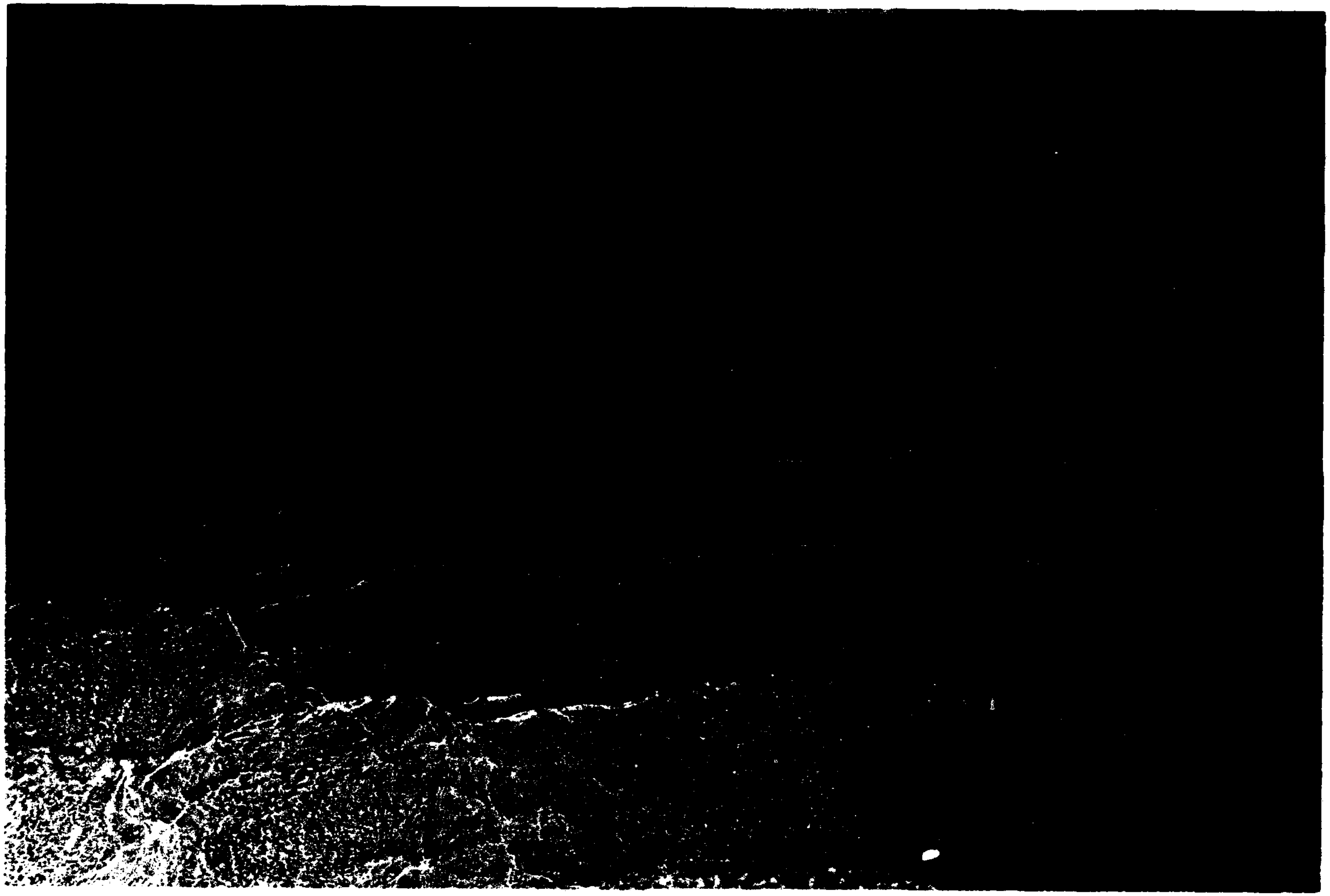


Photo 40. Typical wave and tracer patterns for Base Test; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

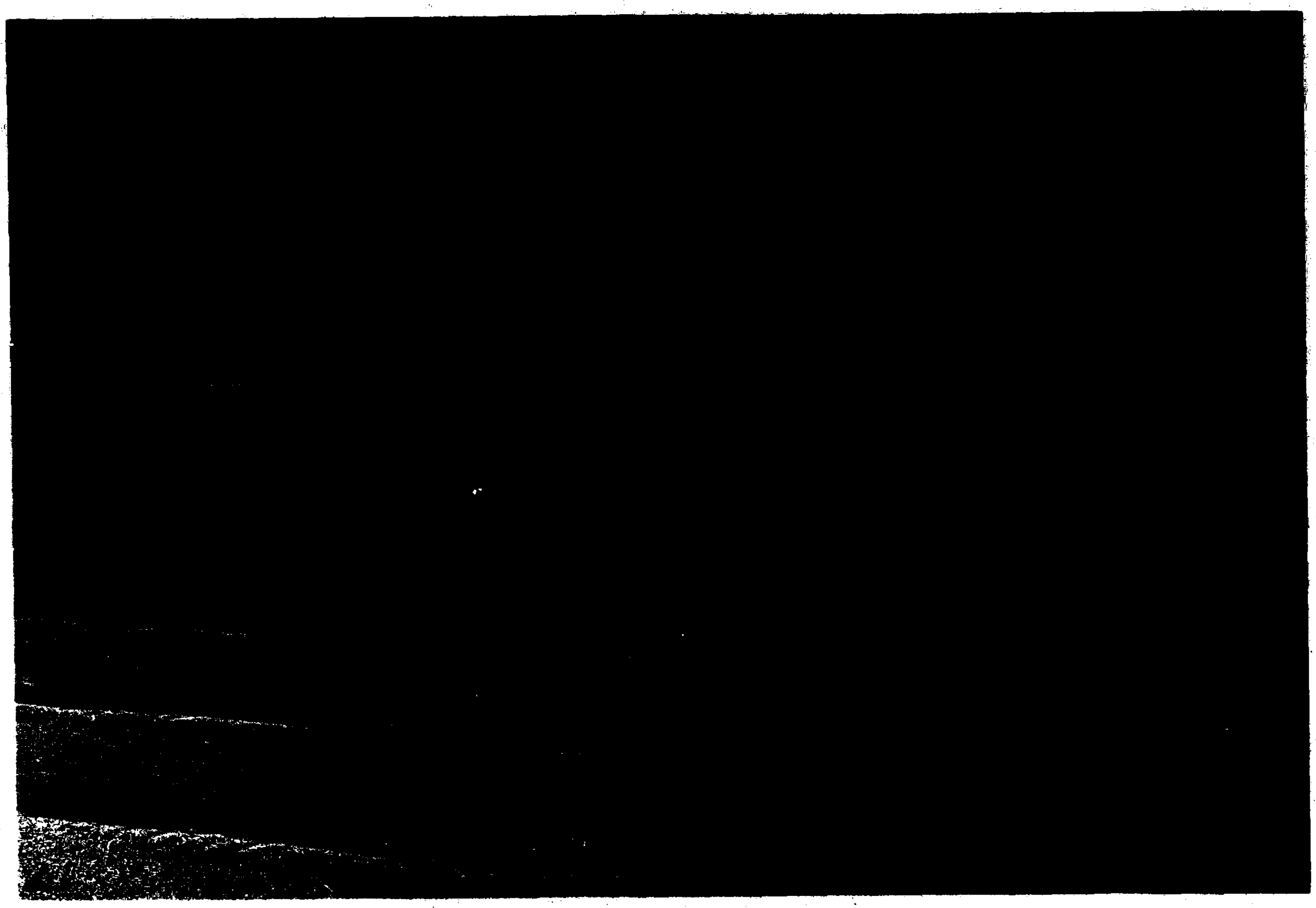


Photo 41. Typical wave and tracer patterns for Base Test; 5.5-sec, 4.4-ft waves from 19 deg; +0.9 ft swl

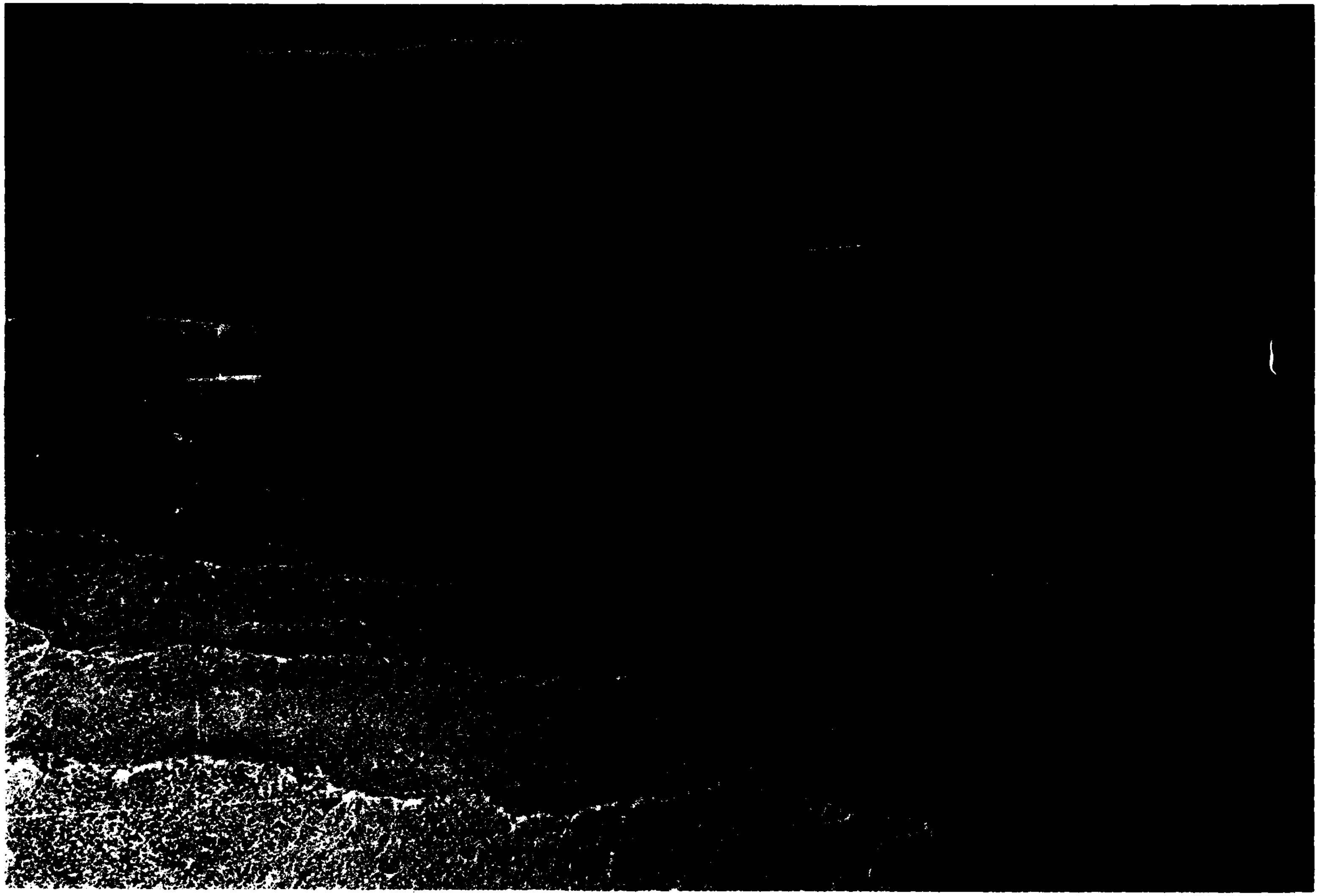


Photo 42. Typical wave and tracer patterns for Base Test; 7.1-sec, 9.1-ft waves from 19 deg; +0.9 ft swl

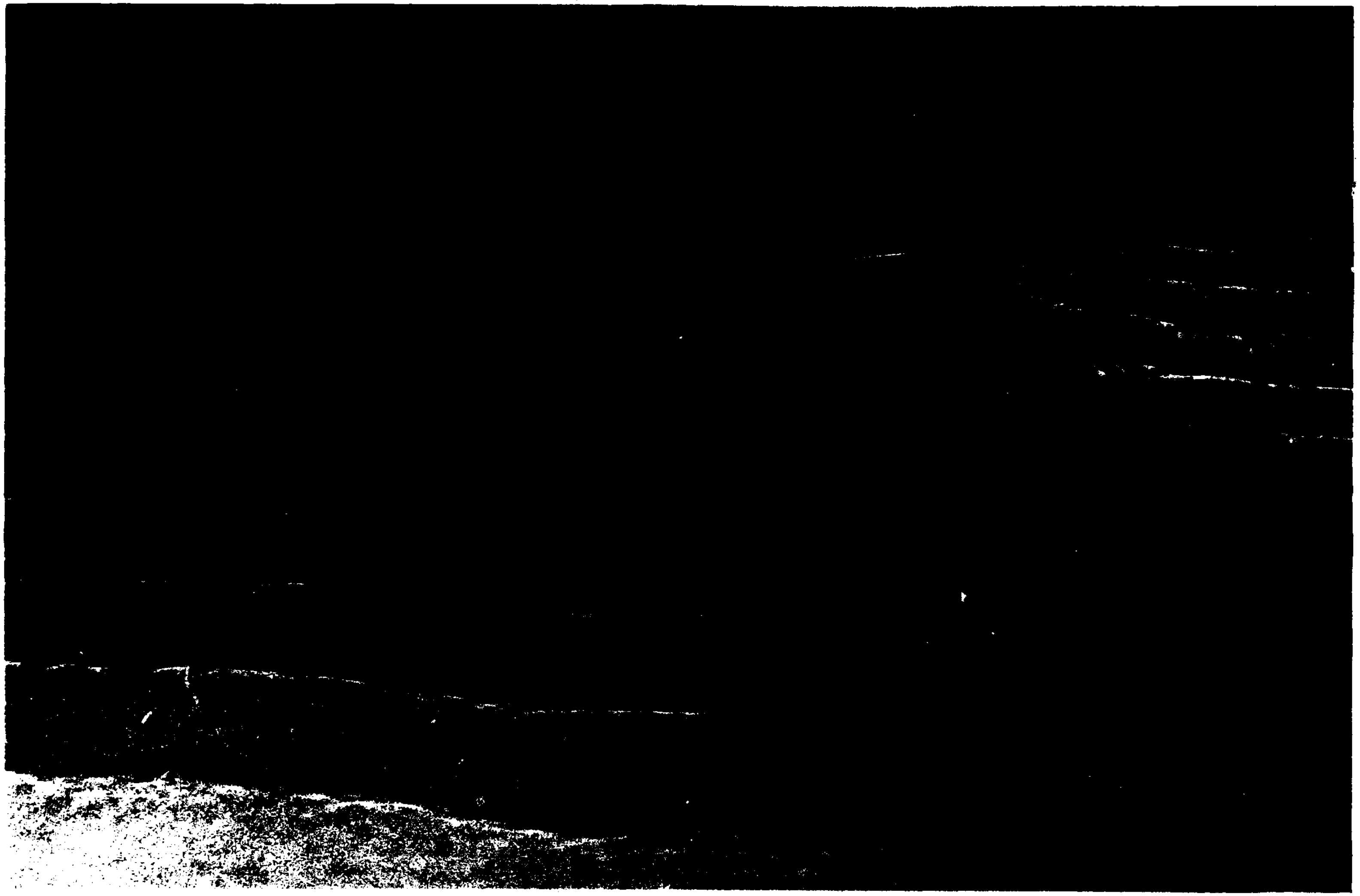


Photo 43. Typical wave and tracer patterns for Base Test; 5.5-sec, 4.4-ft waves from 19 deg; +4.0 ft swl

Photo 44. Typical wave and tracer patterns for Base Test; 7.1-sec, 9.1-ft waves from 19 deg; +4.0 ft swl

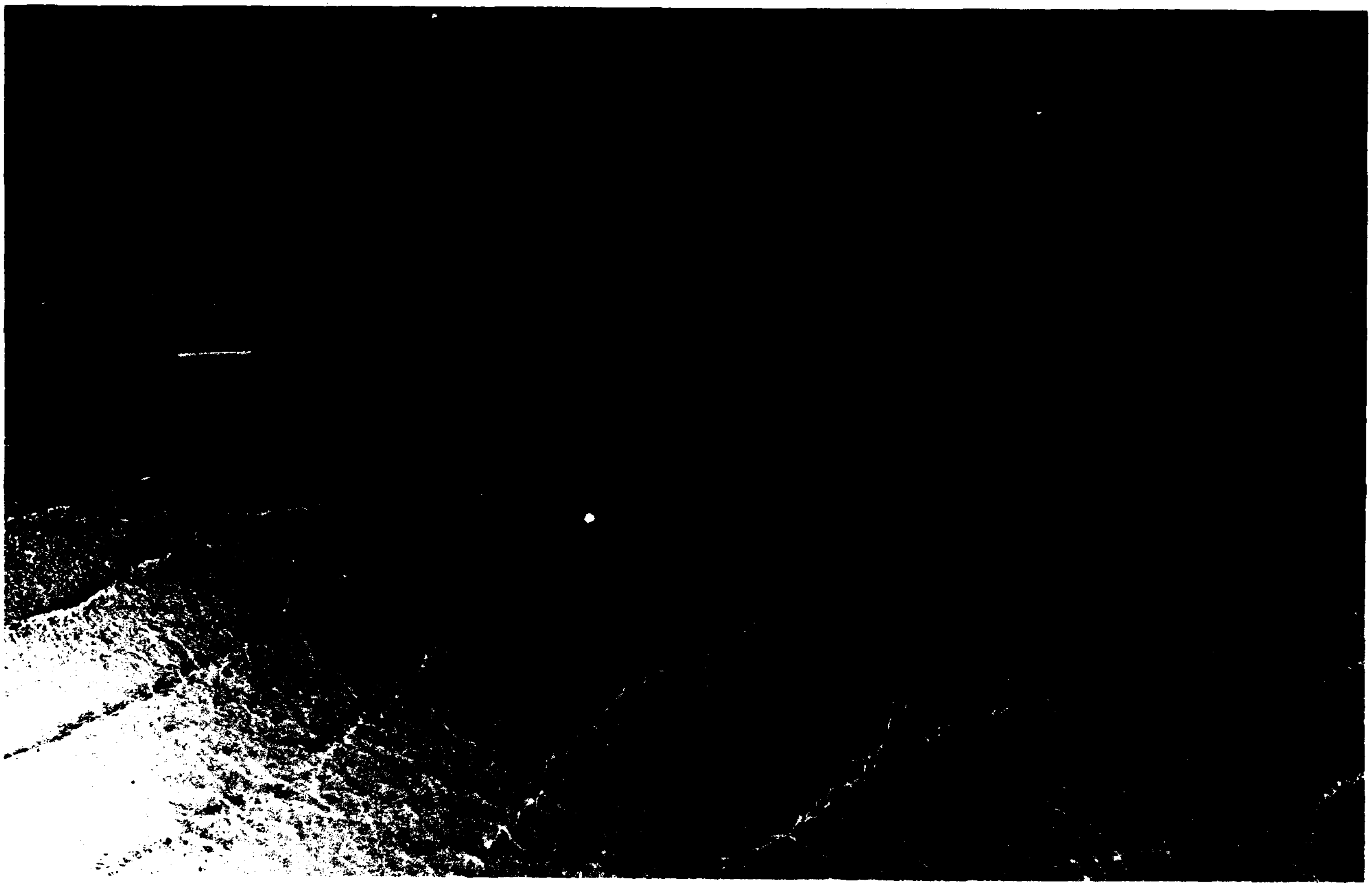


Photo 45. Typical wave patterns for Plan 1; 7.4-sec, 7.5-ft waves from 287 deg; +0.9 ft swl

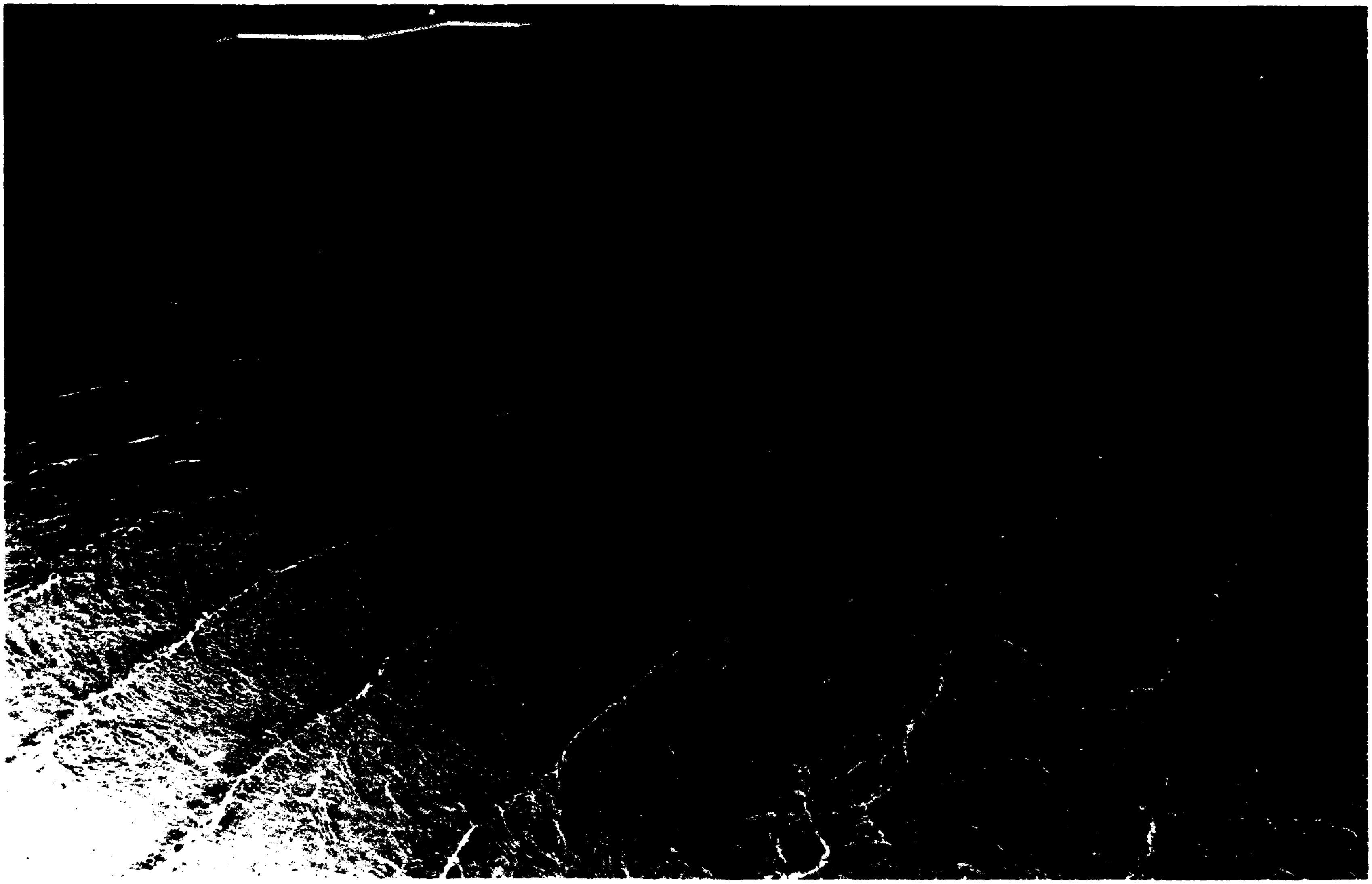


Photo 46. Typical wave patterns for Plan 1; 7.4-sec, 7.5-ft waves from 287 deg; +4.0 ft swl

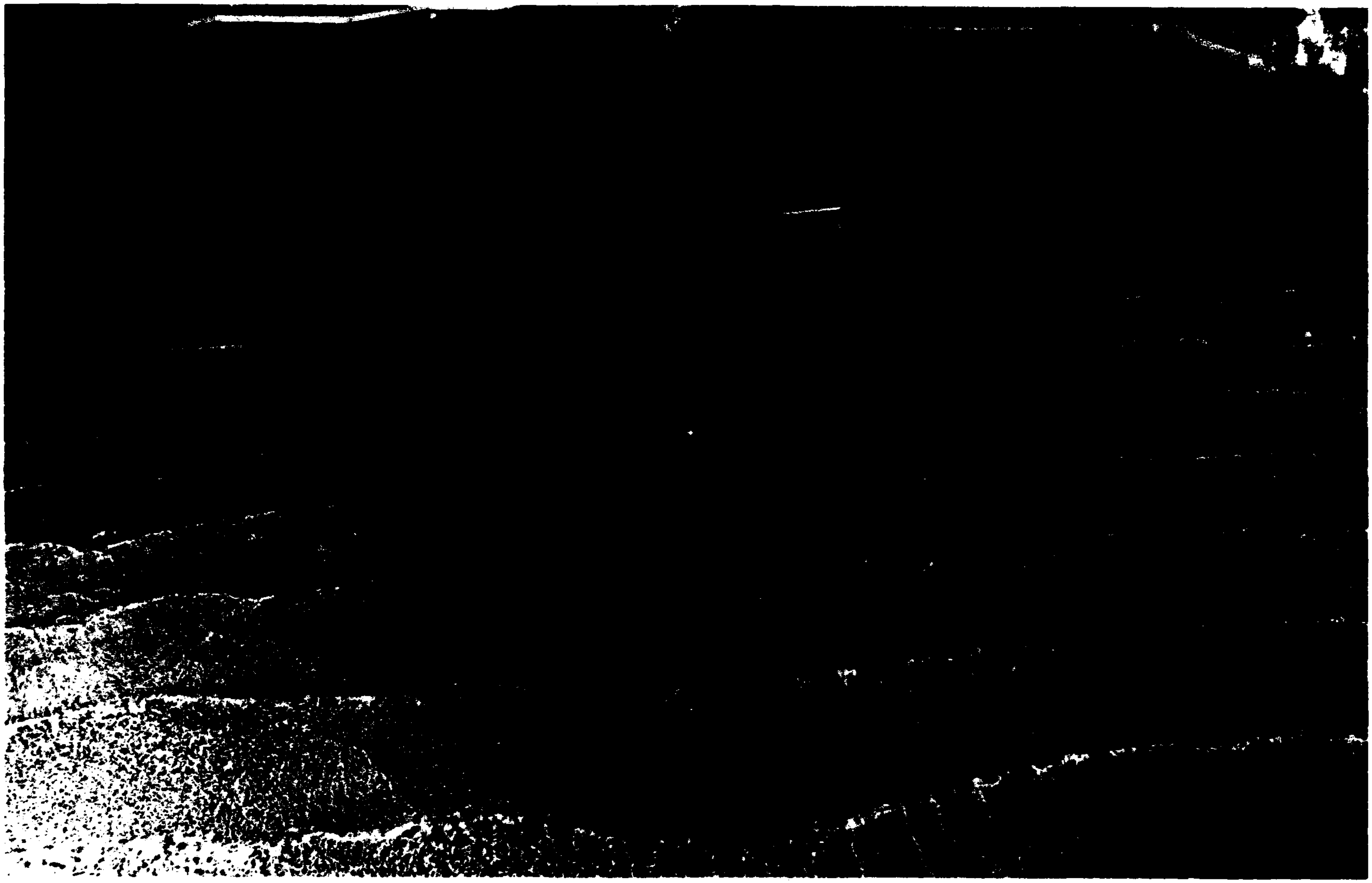


Photo 47. Typical wave patterns for Plan 1; 6.5-sec, 7.1-ft waves from 357 deg; +0.9 ft swl

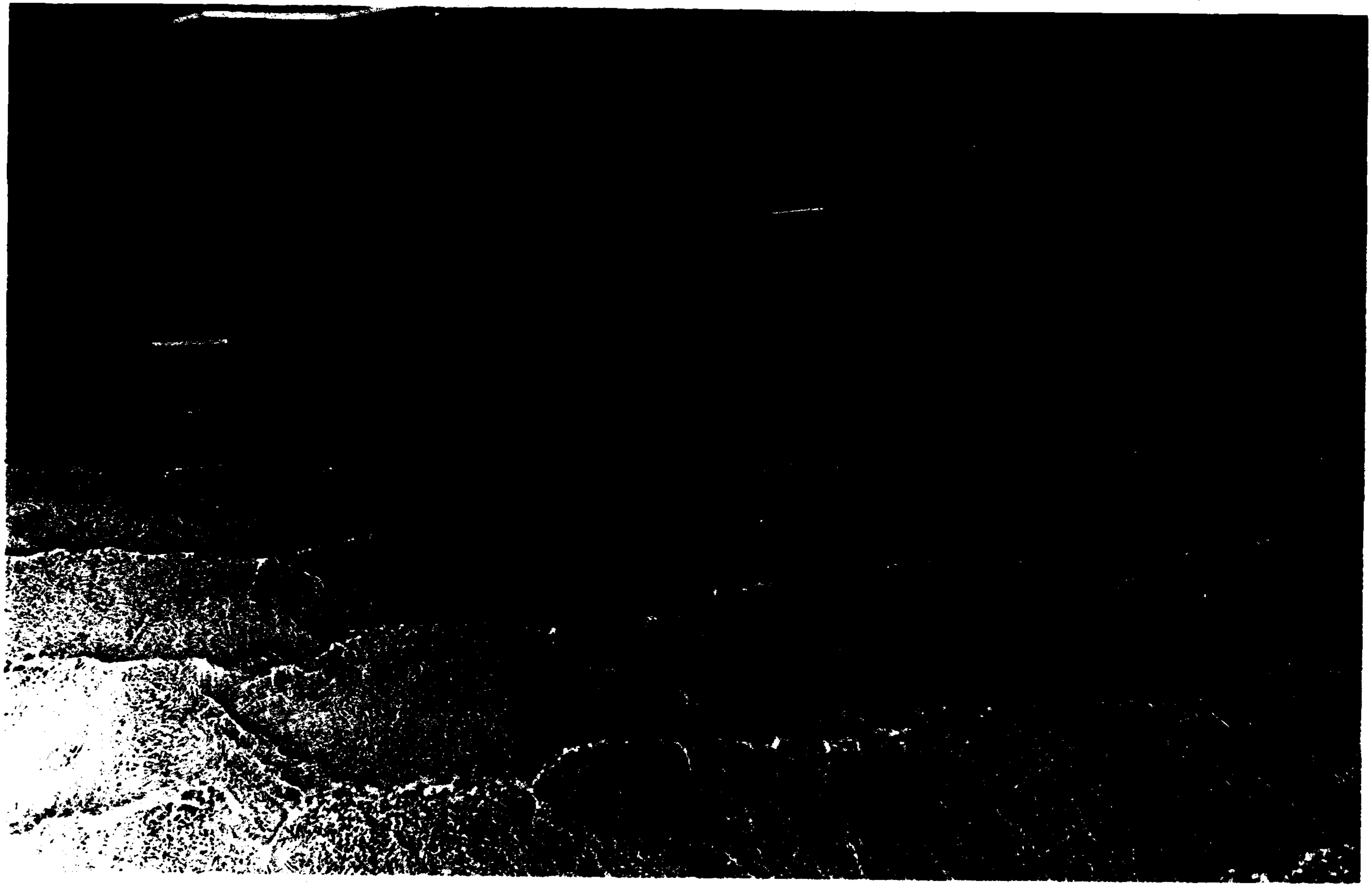


Photo 48. Typical wave patterns for Plan 1; 7.8-sec, 10.9-ft waves from 357 deg; +0.9 ft swl

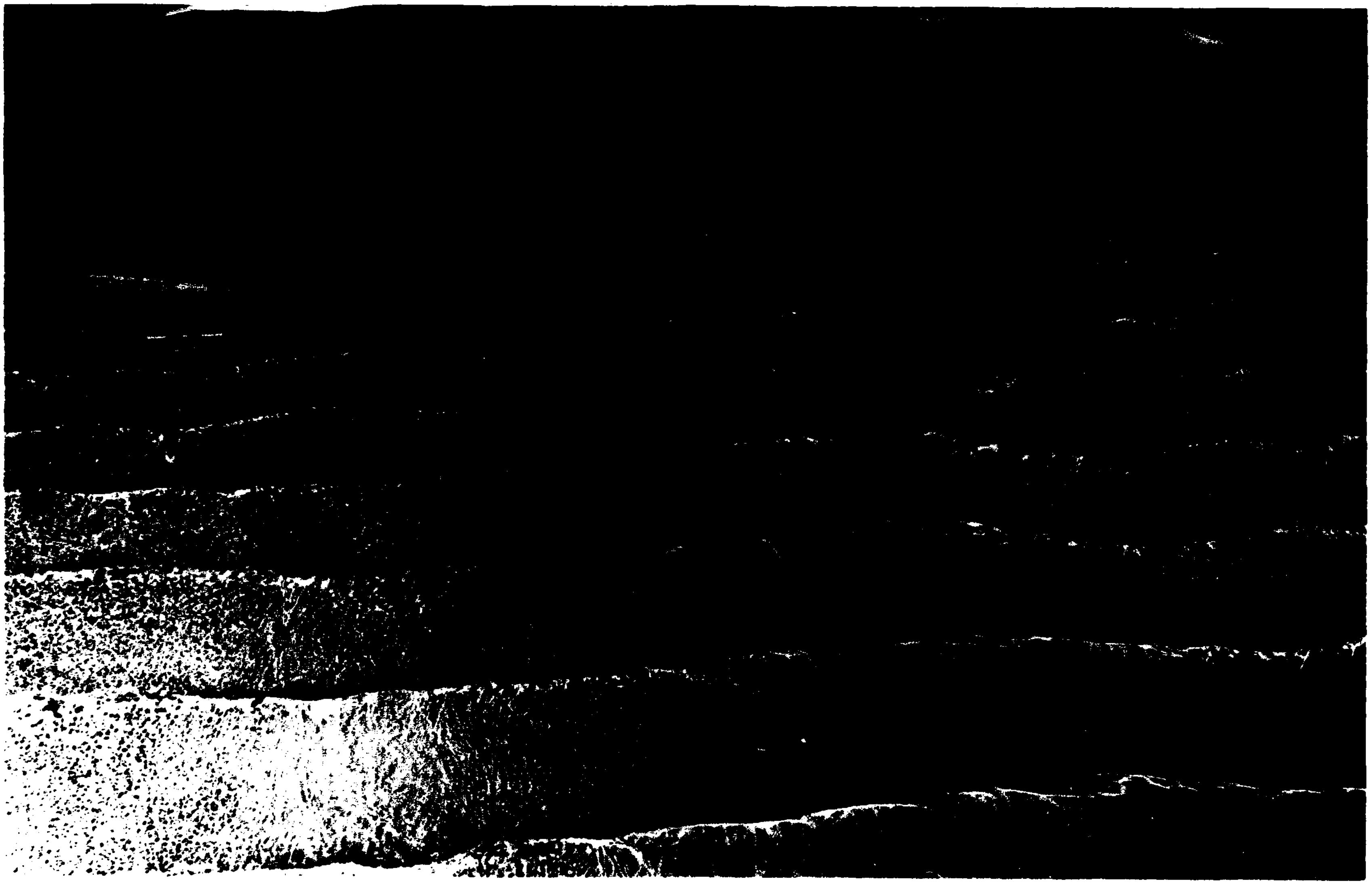


Photo 49. Typical wave patterns for Plan 1; 6.5-sec, 7.1-ft waves from 357 deg; +4.0 ft swl

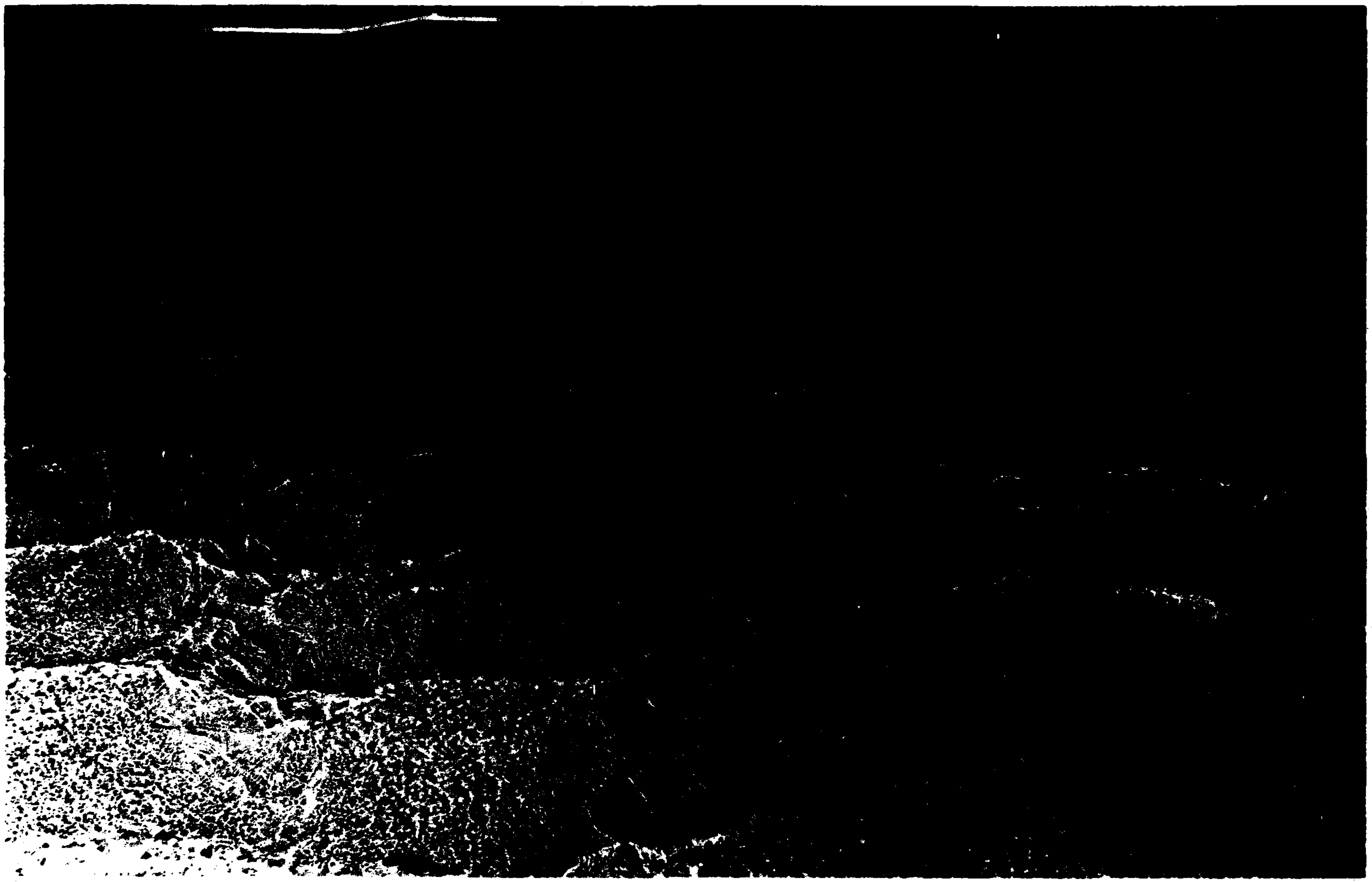


Photo 50. Typical wave patterns for Plan 1; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

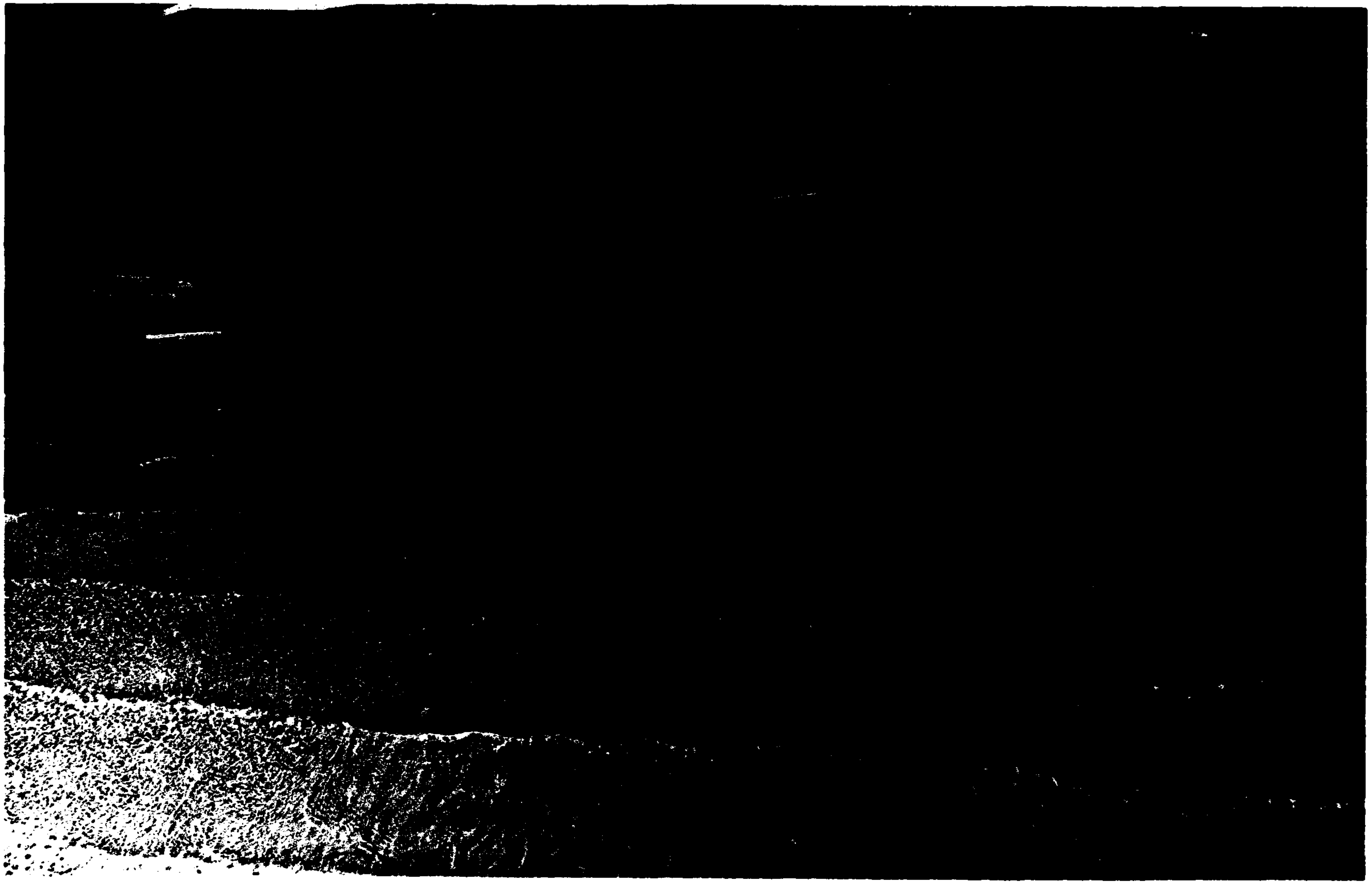


Photo 51. Typical wave patterns for Plan 1; 6.2-sec, 6.3-ft waves from 19 deg; +0.9 ft swl

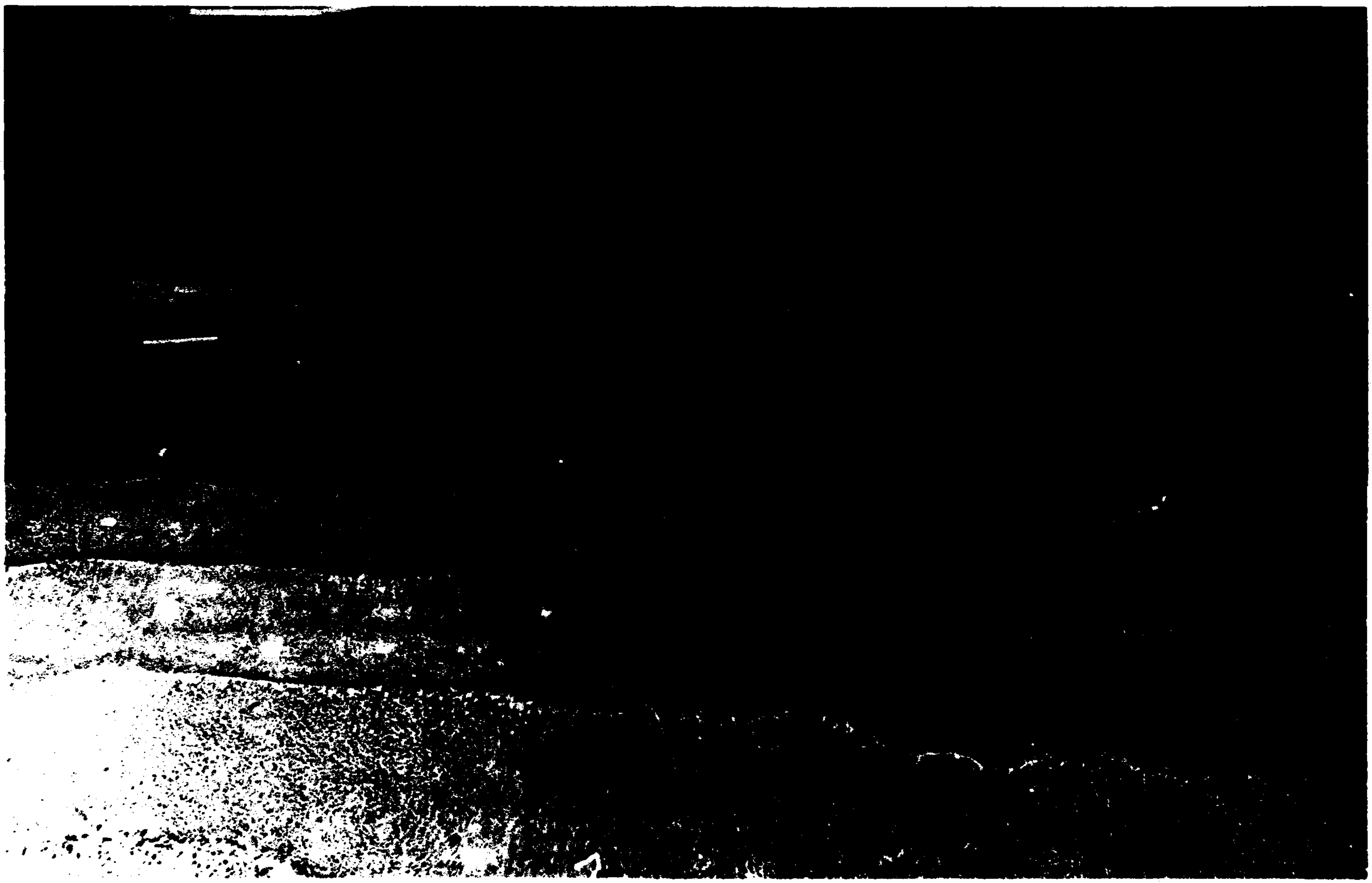


Photo 52. Typical wave patterns for Plan 1; 7.1-sec, 9.1-ft waves from 19 deg; +0.9 ft swl

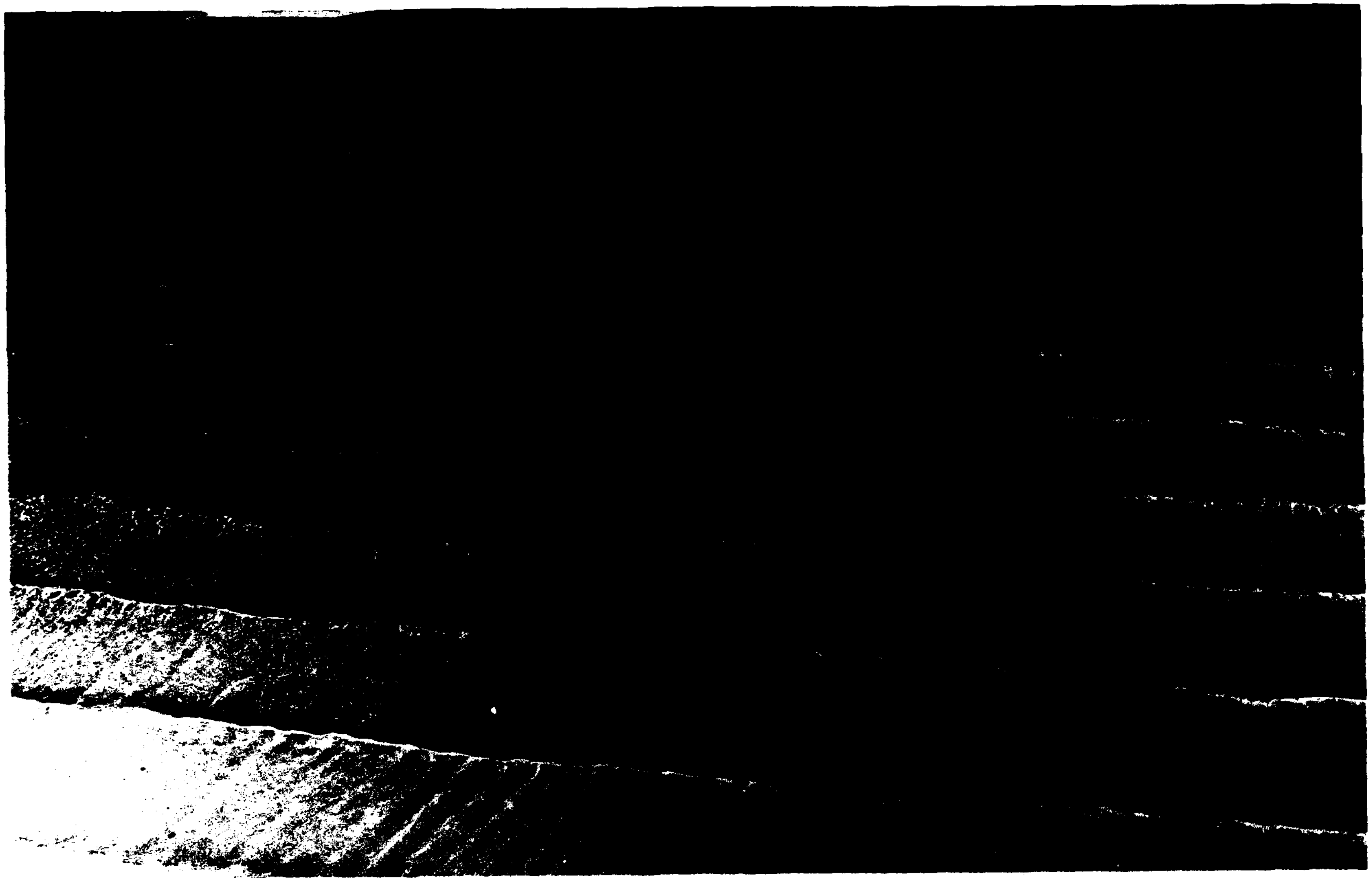


Photo 53. Typical wave patterns for Plan 1; 6.2-sec, 6.3-ft waves from 19 deg; +4.0 ft swl

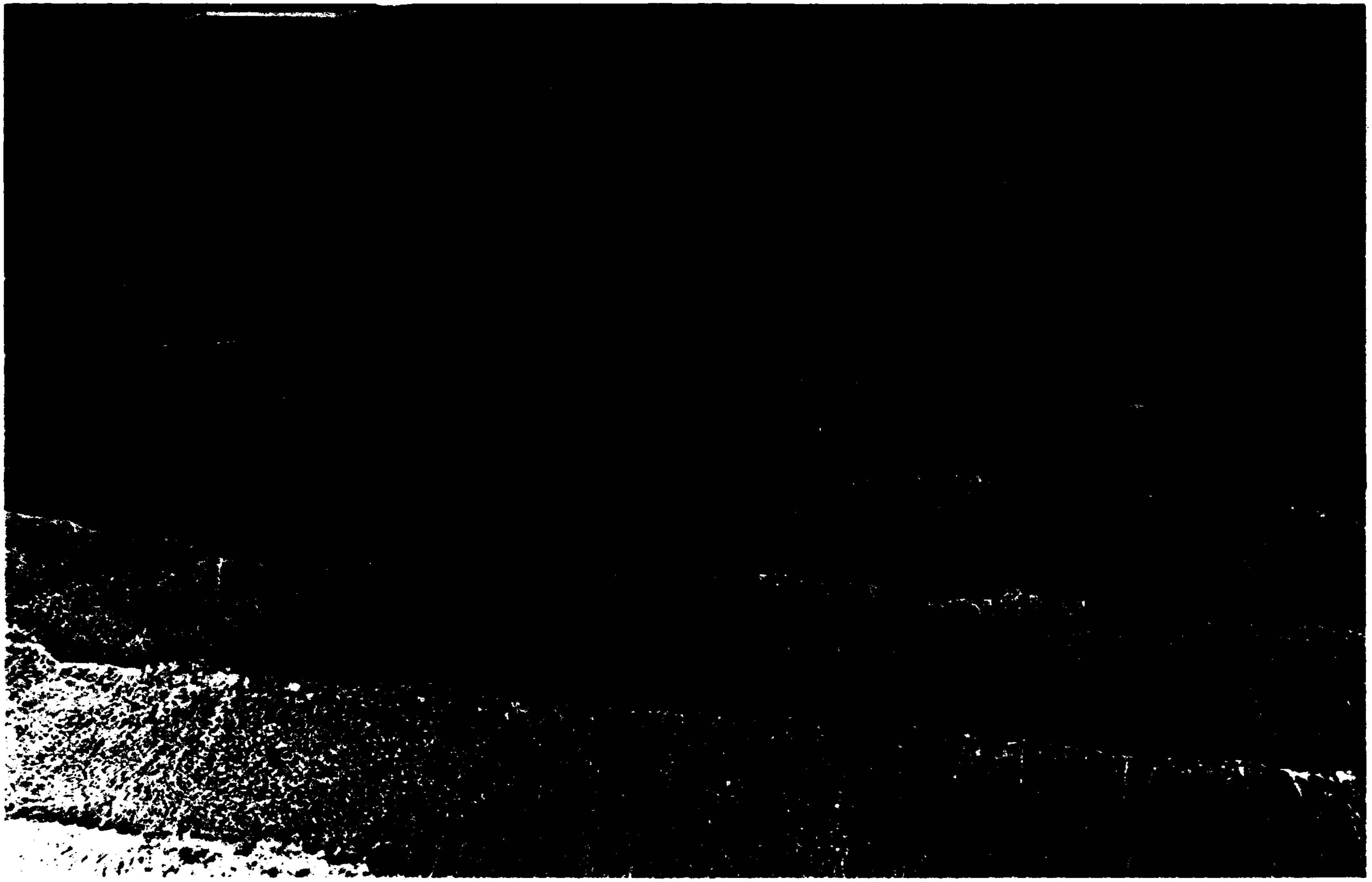


Photo 54. Typical wave patterns for Plan 1; 7.1-sec, 9.1-ft waves from 19 deg; +4.0 ft swl

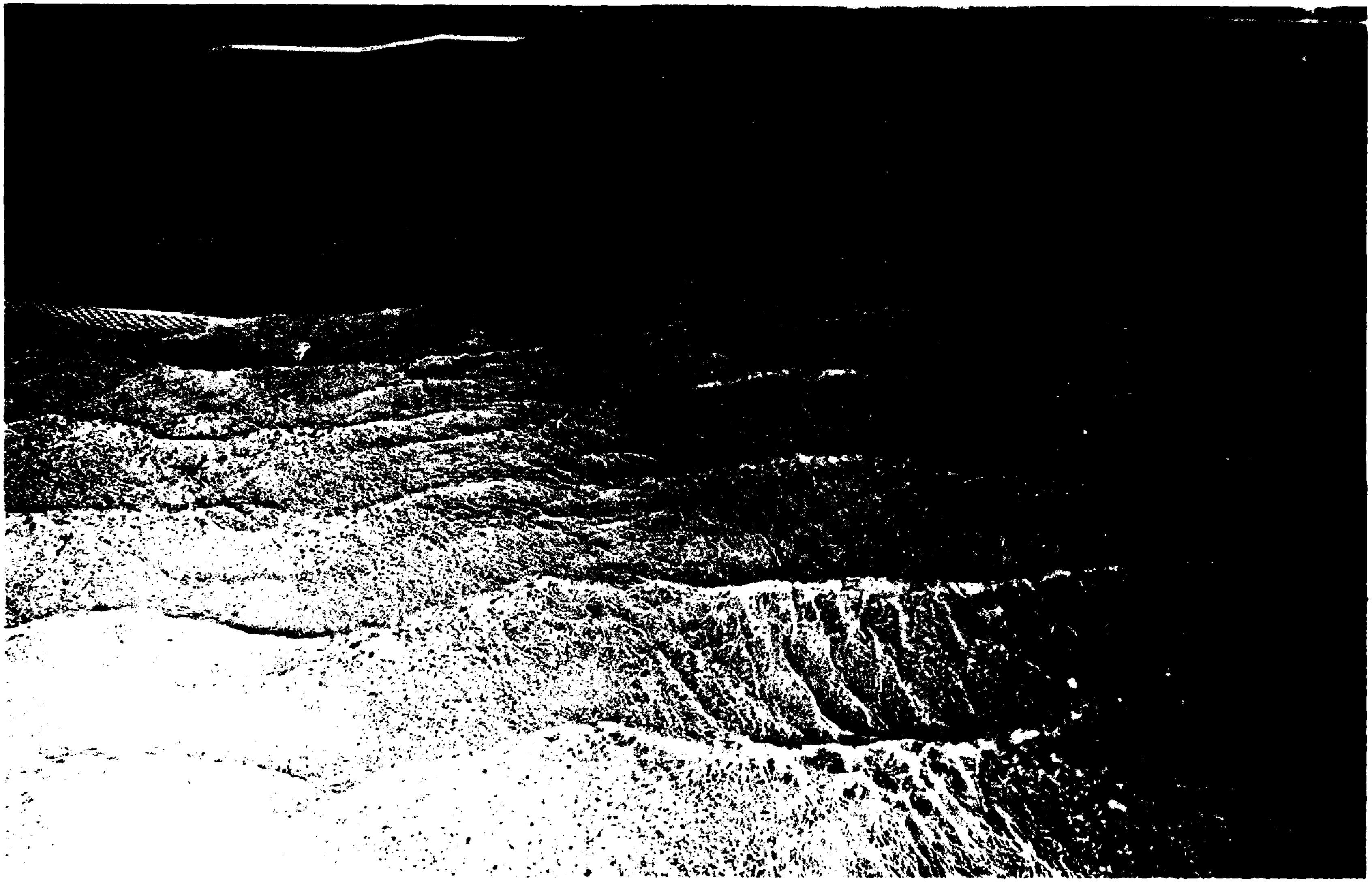


Photo 55. Typical wave patterns for Plan 2; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

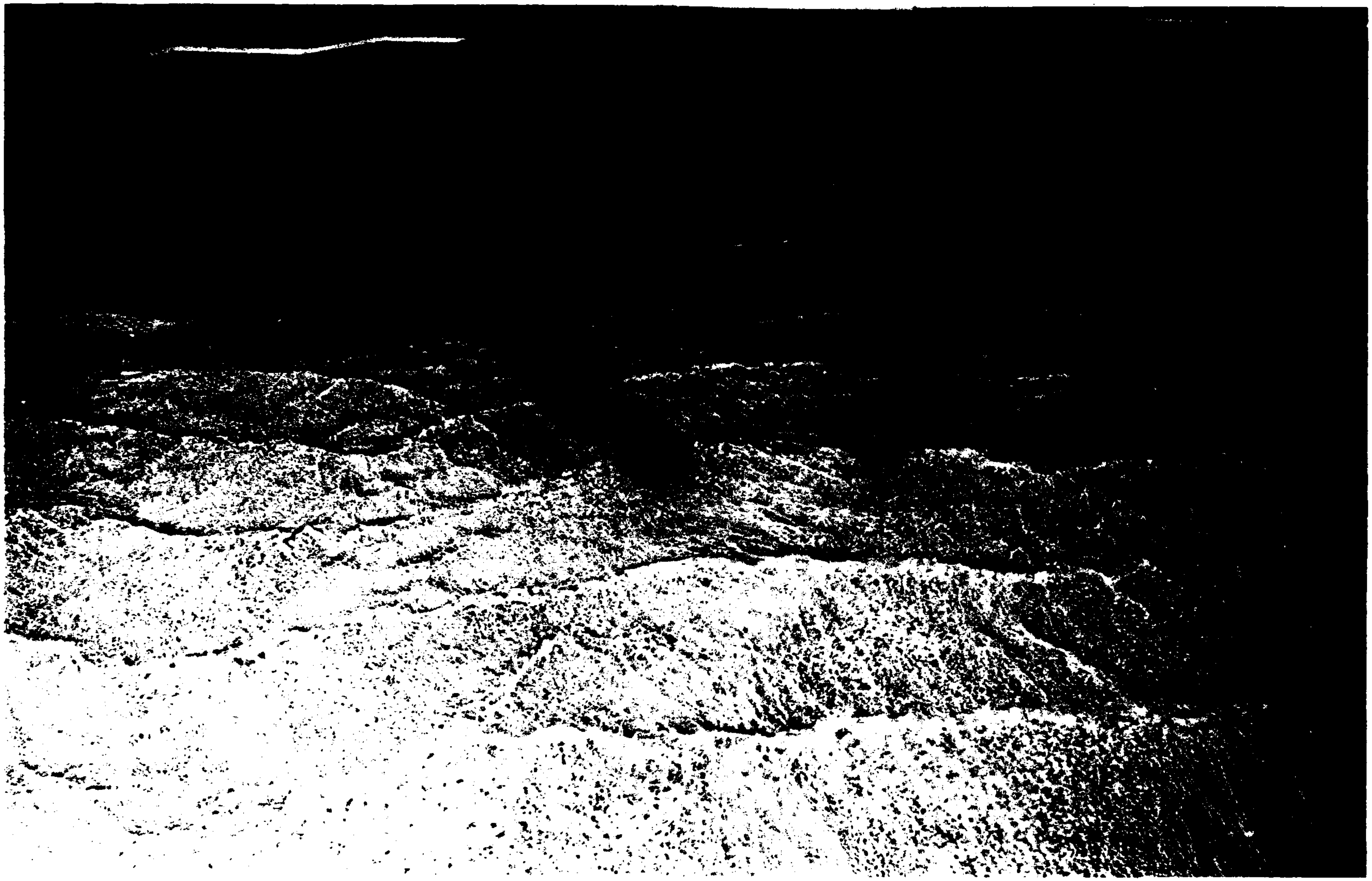


Photo 56. Typical wave patterns for Plan 2A; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 57. Typical wave patterns for Plan 2B; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 58. Typical wave patterns for Plan 2C; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 59. Typical wave patterns for Plan 2D; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

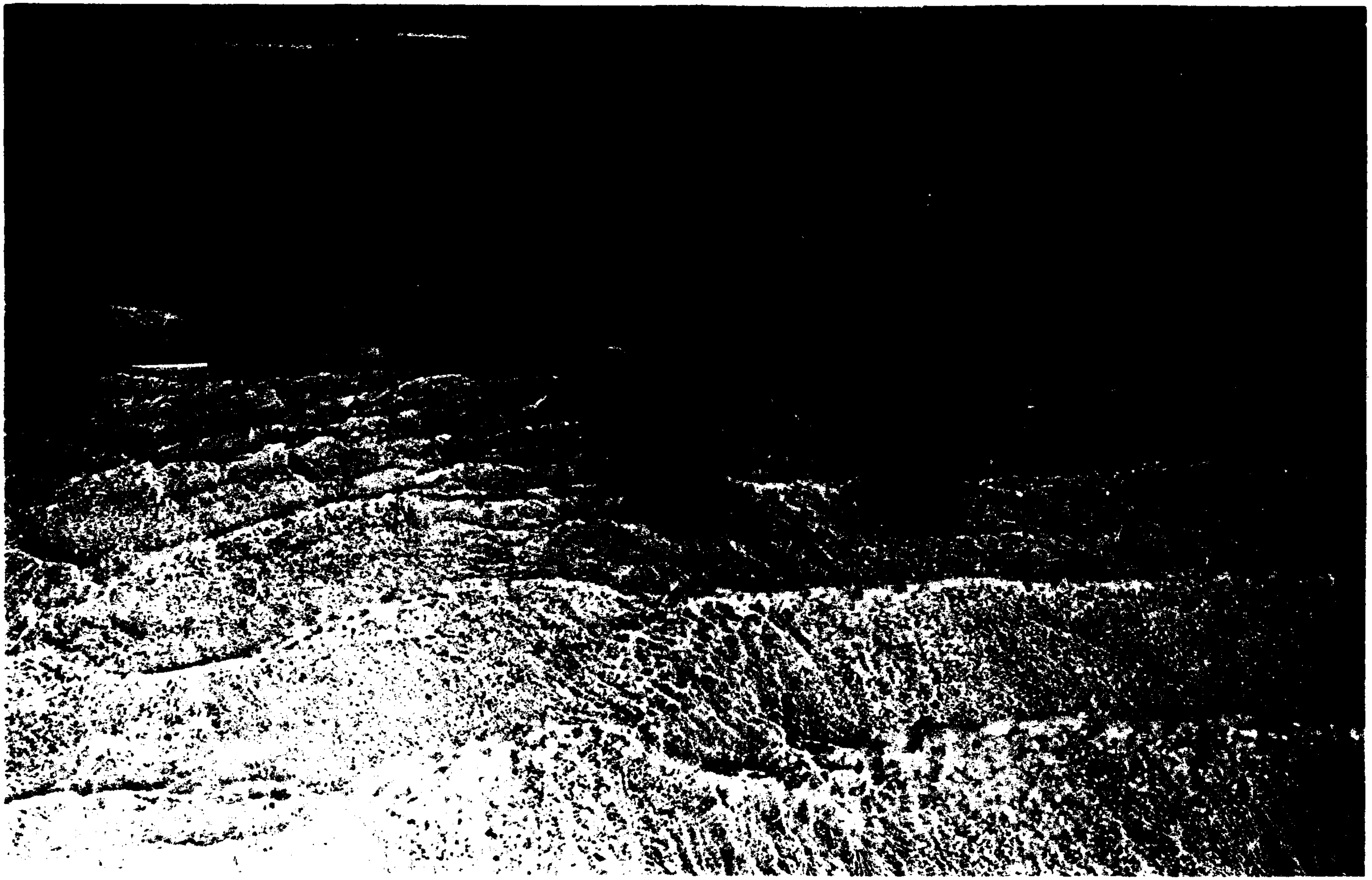


Photo 60. Typical wave patterns for Plan 2E; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

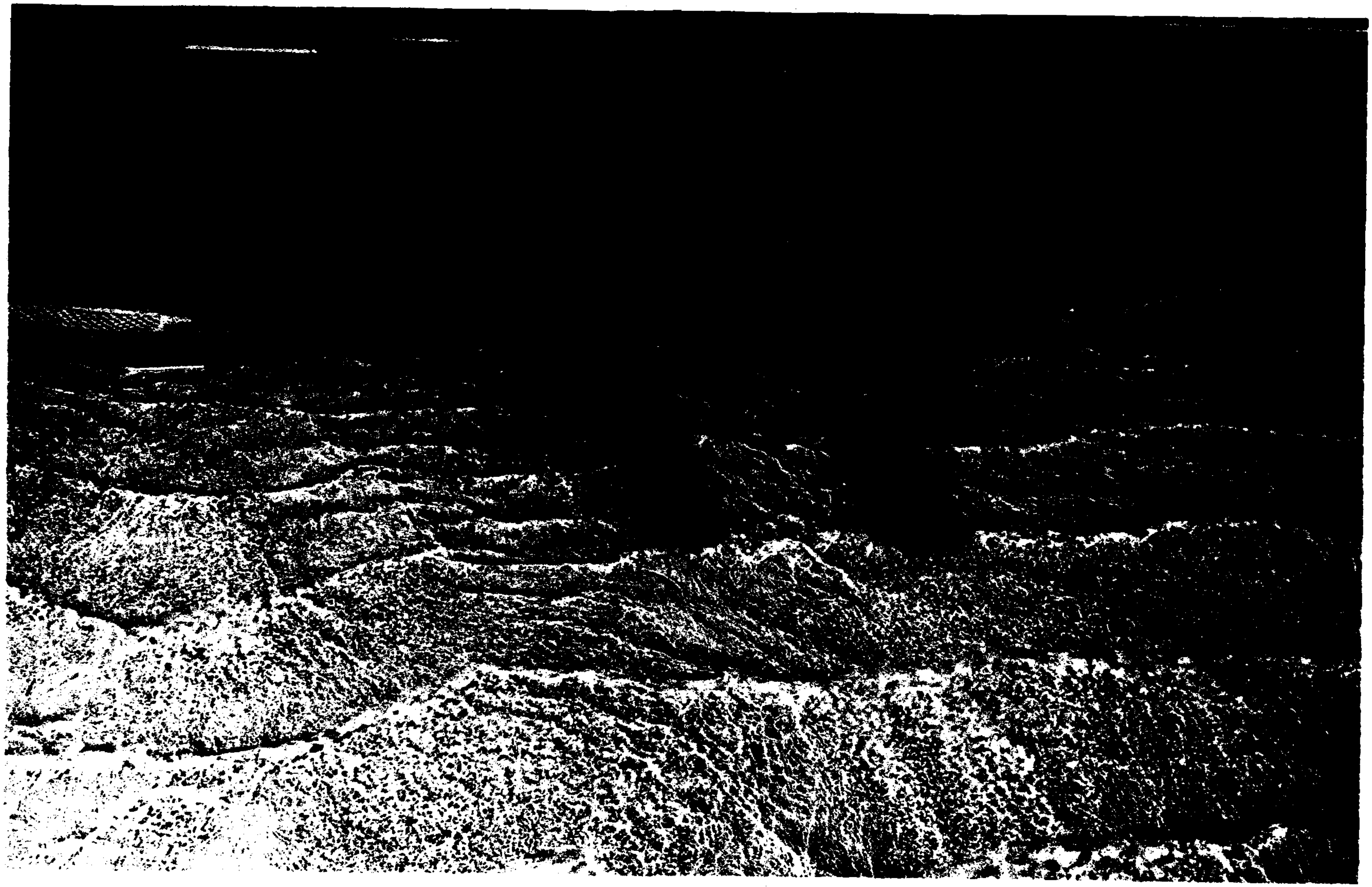


Photo 61. Typical wave patterns for Plan 2F; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 62. Typical wave patterns for Plan 2G; 7.6-sec, 10.4-ft waves from 357 deg; +4.4 ft swl

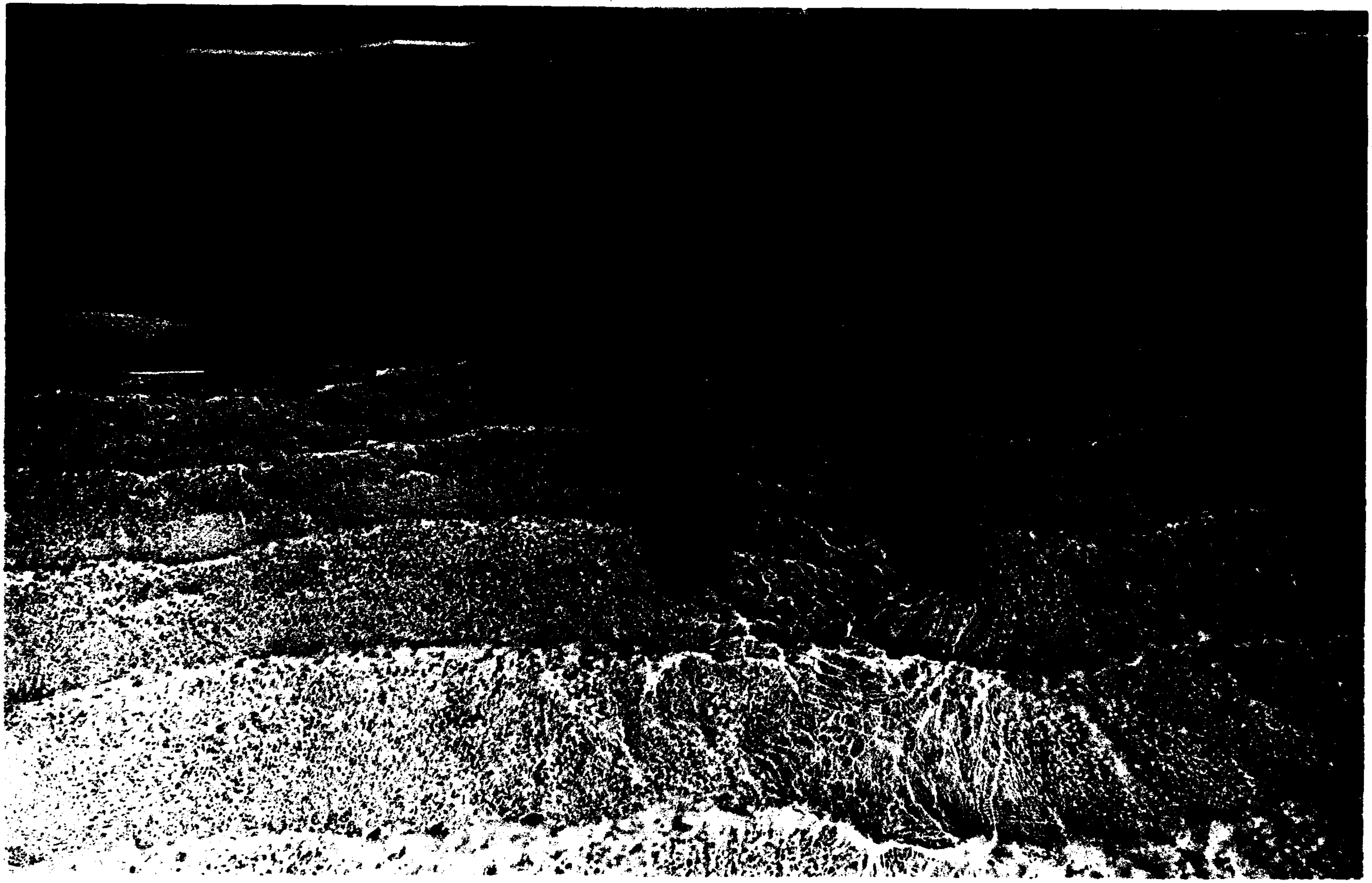


Photo 63. Typical wave patterns for Plan 2H; 7.6-sec, 10.4-ft waves from 357 deg; +4.4 ft swl

Photo 64. Typical wave patterns for Plan 3; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

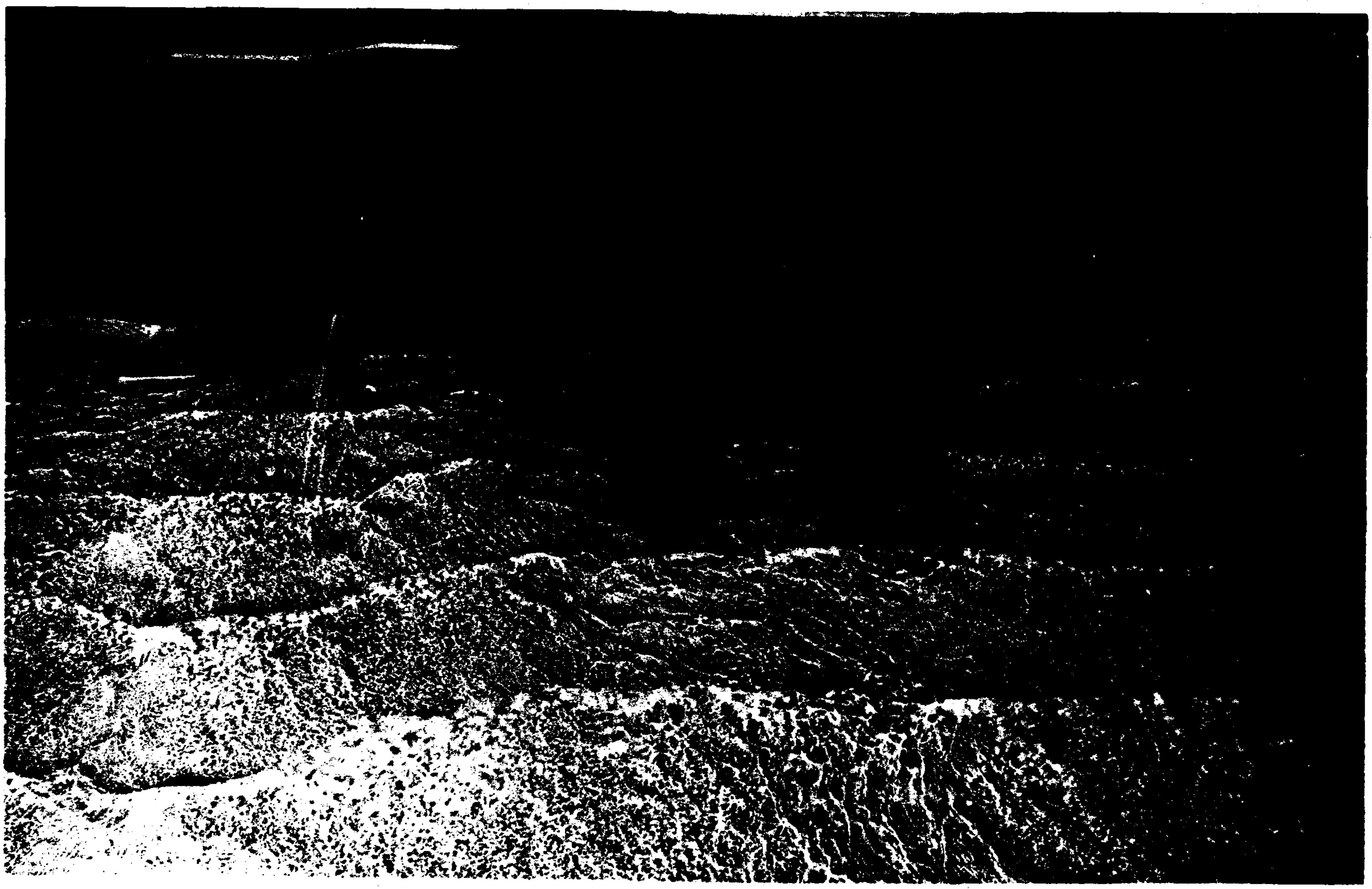


Photo 65. Typical wave patterns for Plan 3A; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 66. Typical wave patterns for Plan 3B; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

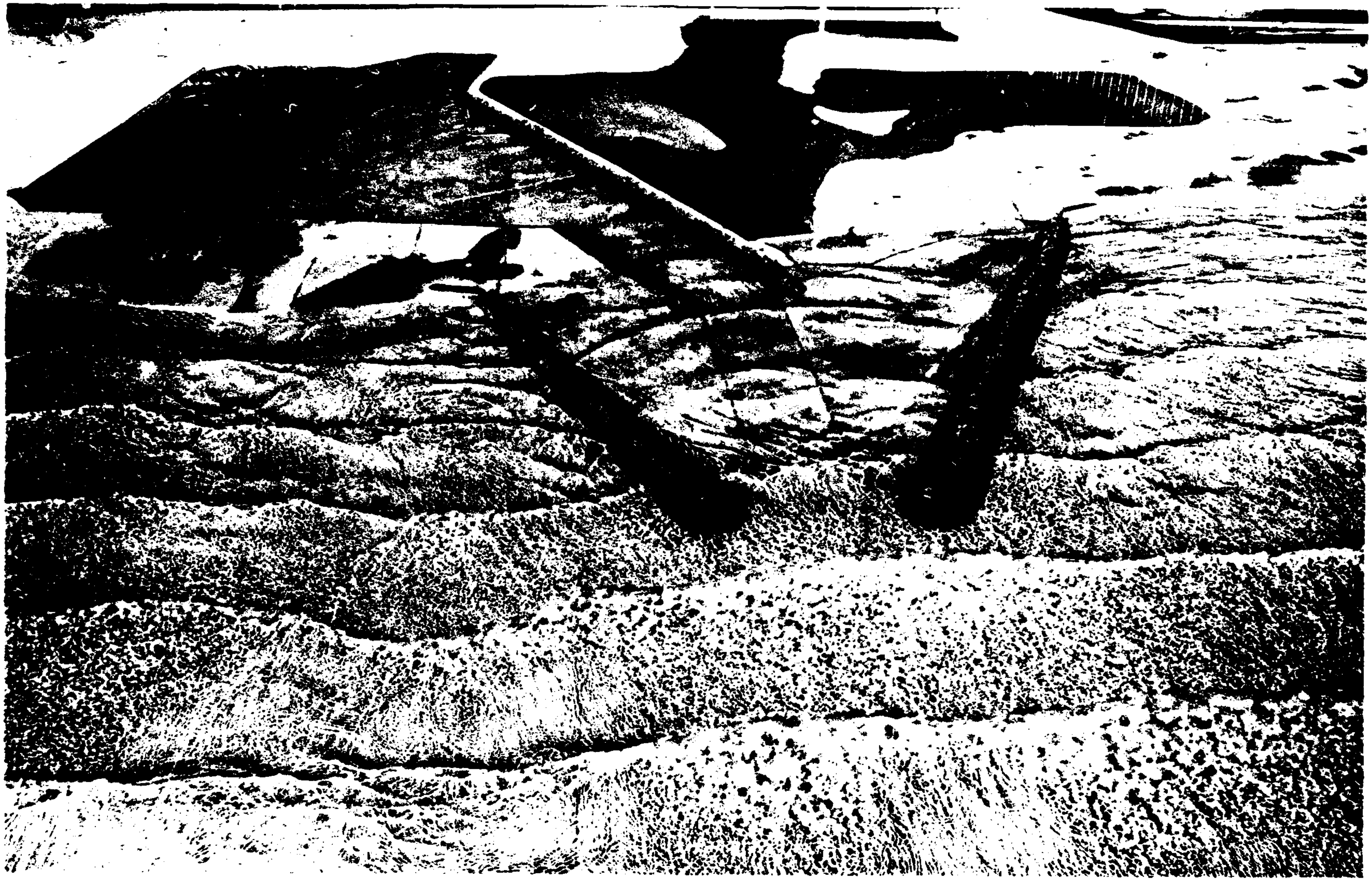


Photo 67. Typical wave patterns for Plan 4; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

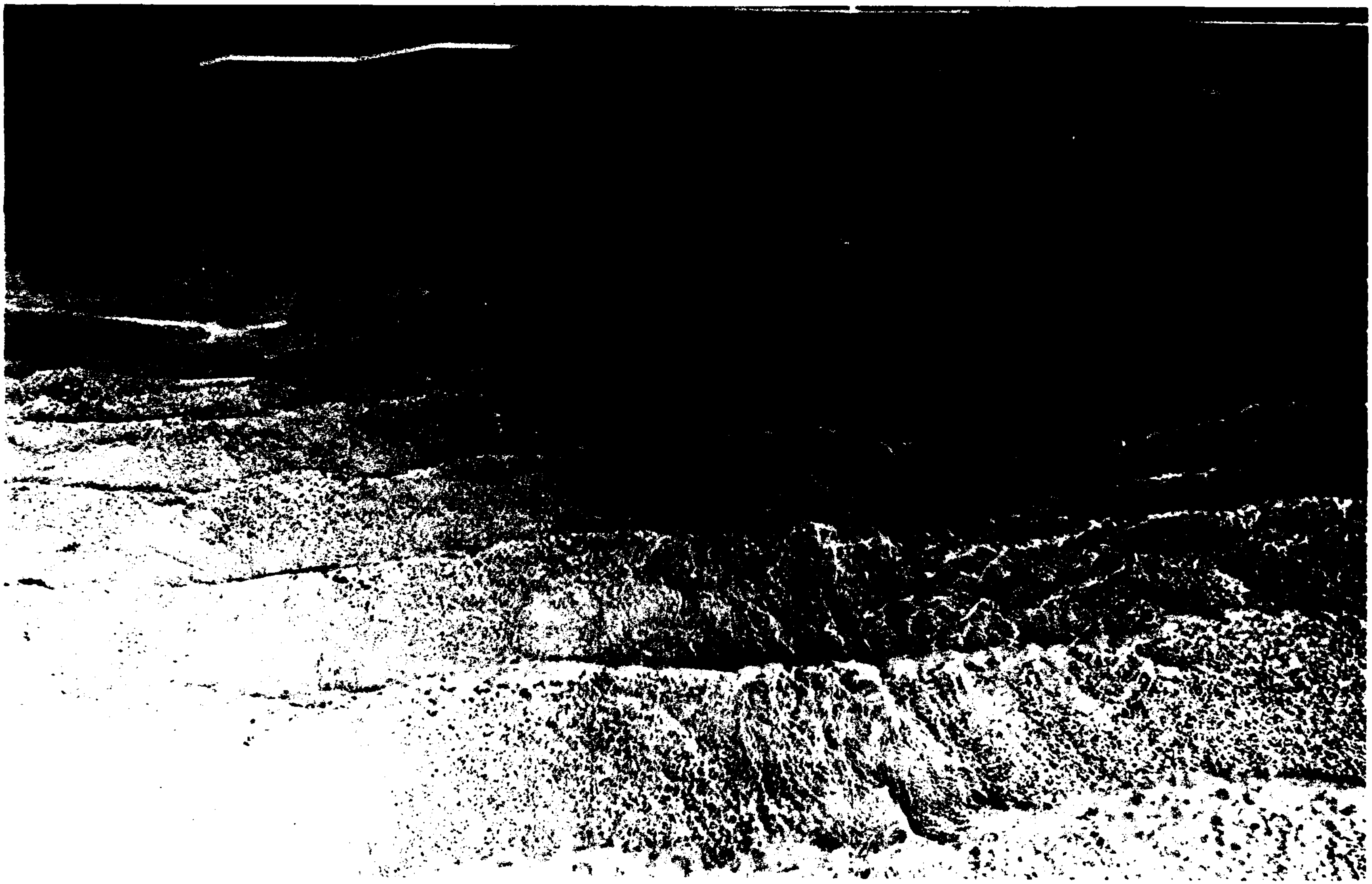


Photo 68. Typical wave patterns for Plan 5; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

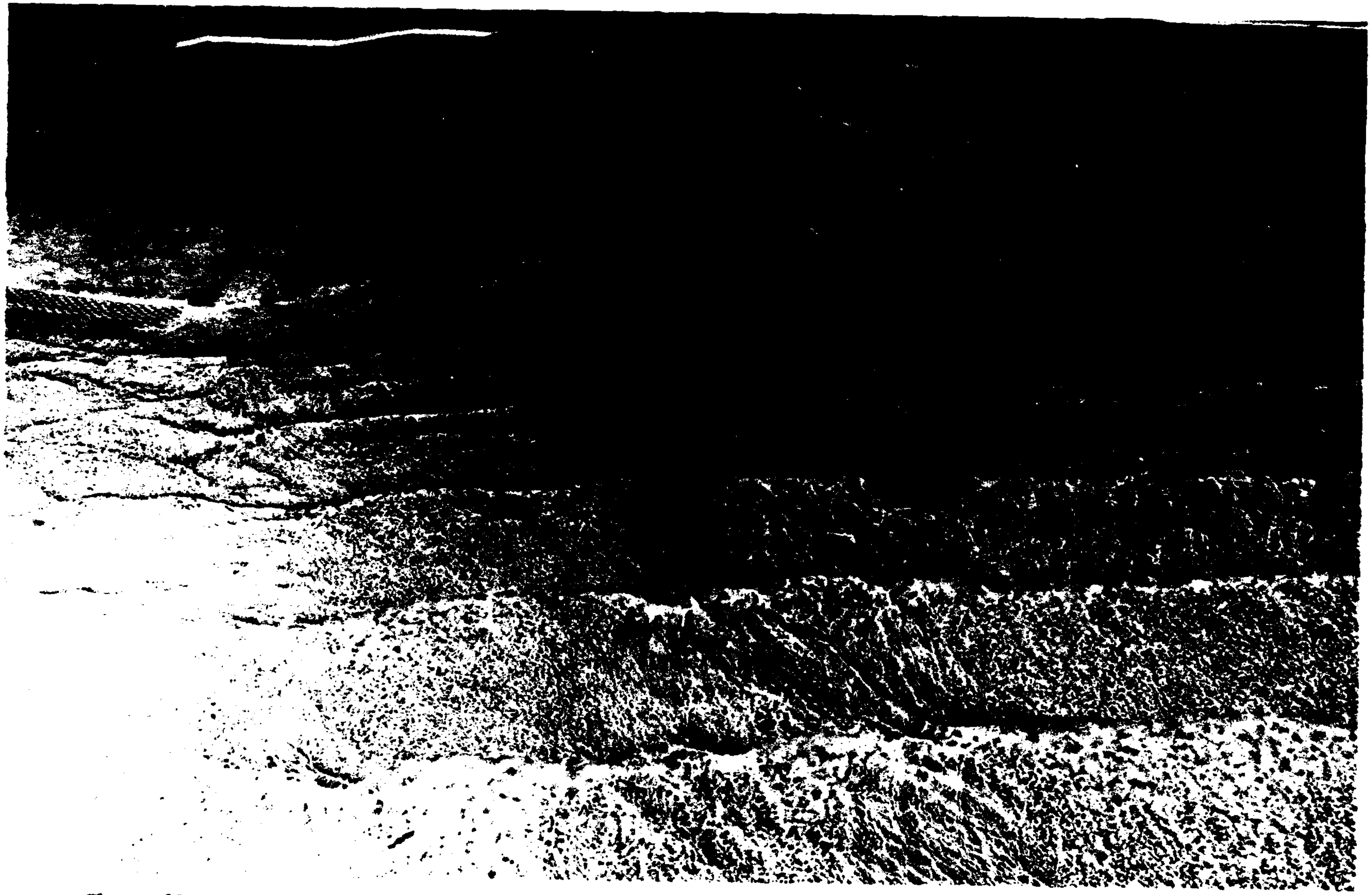


Photo 69. Typical wave patterns for Plan 5A; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

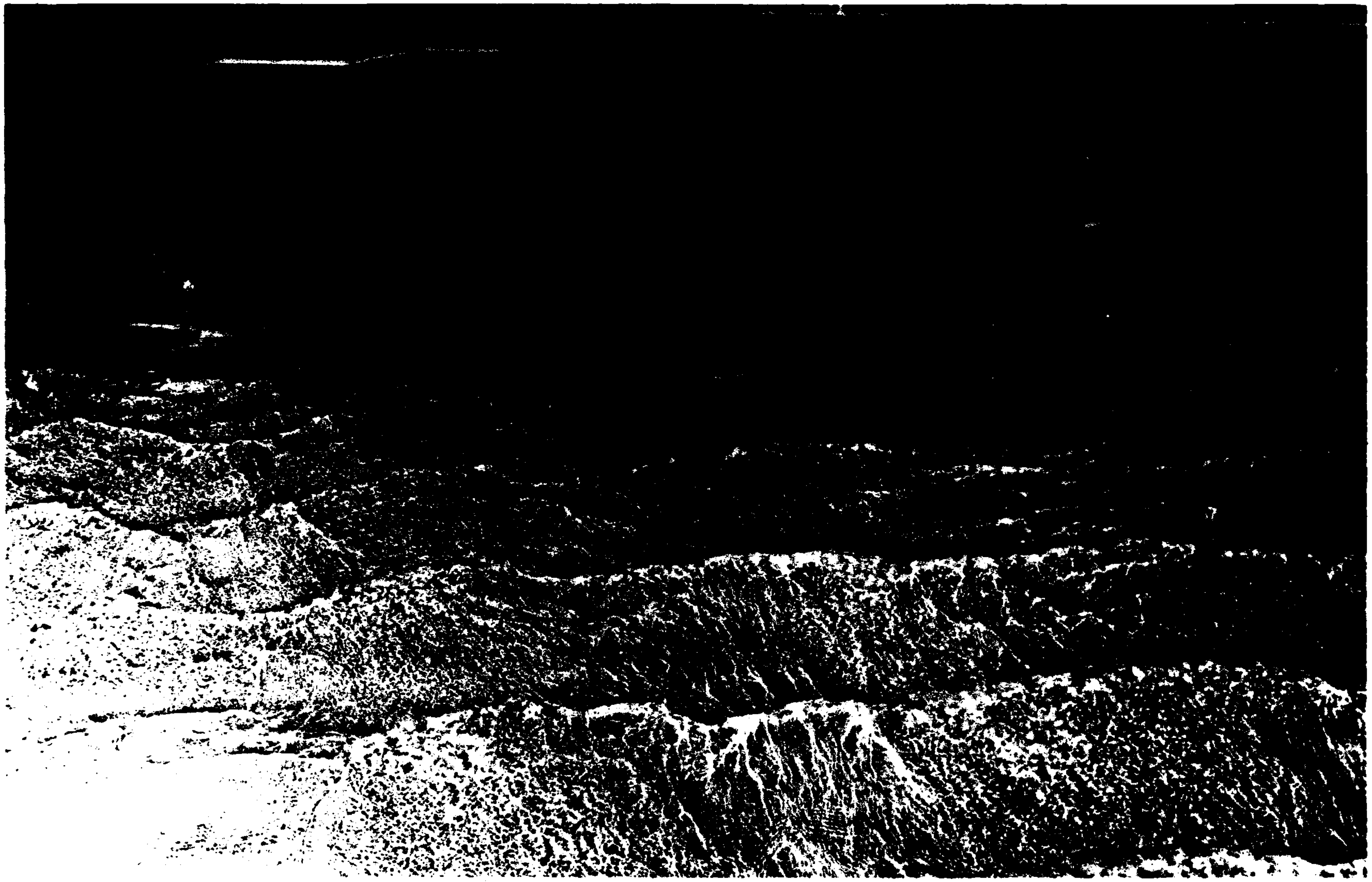


Photo 70. Typical wave patterns for Plan 6; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

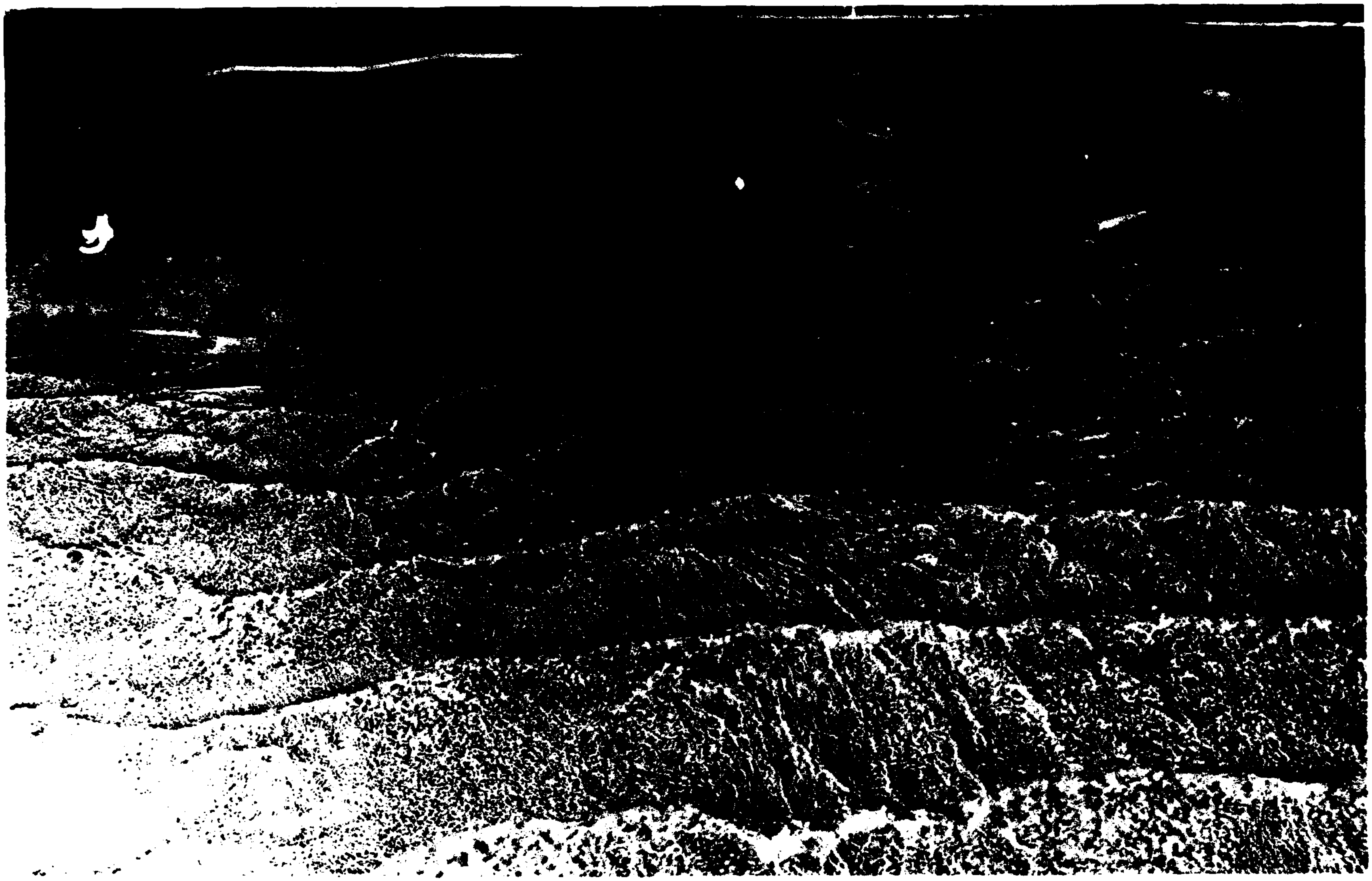


Photo 71. Typical wave patterns for Plan 6A; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

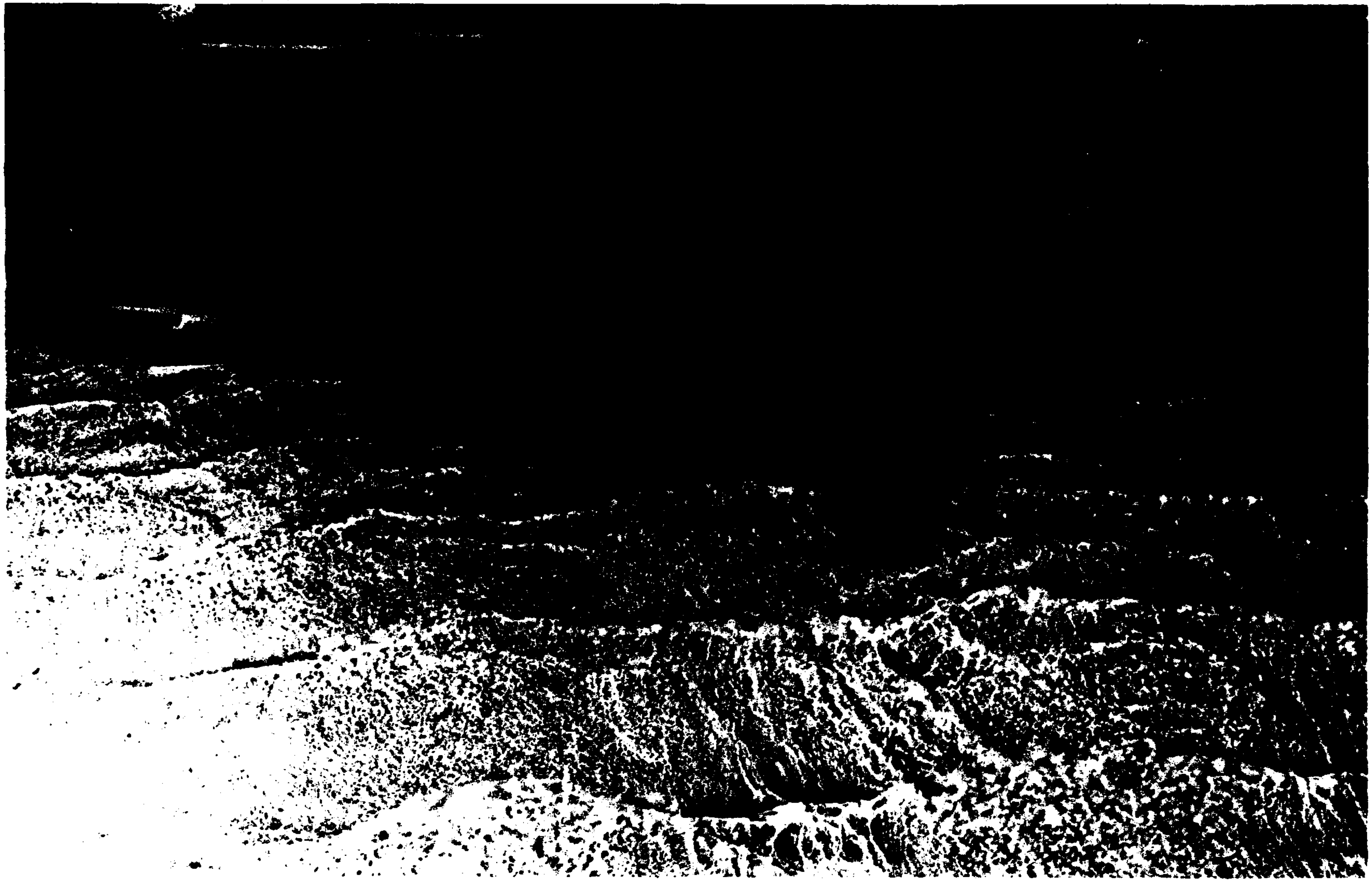


Photo 72. Typical wave patterns for Plan 6B; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

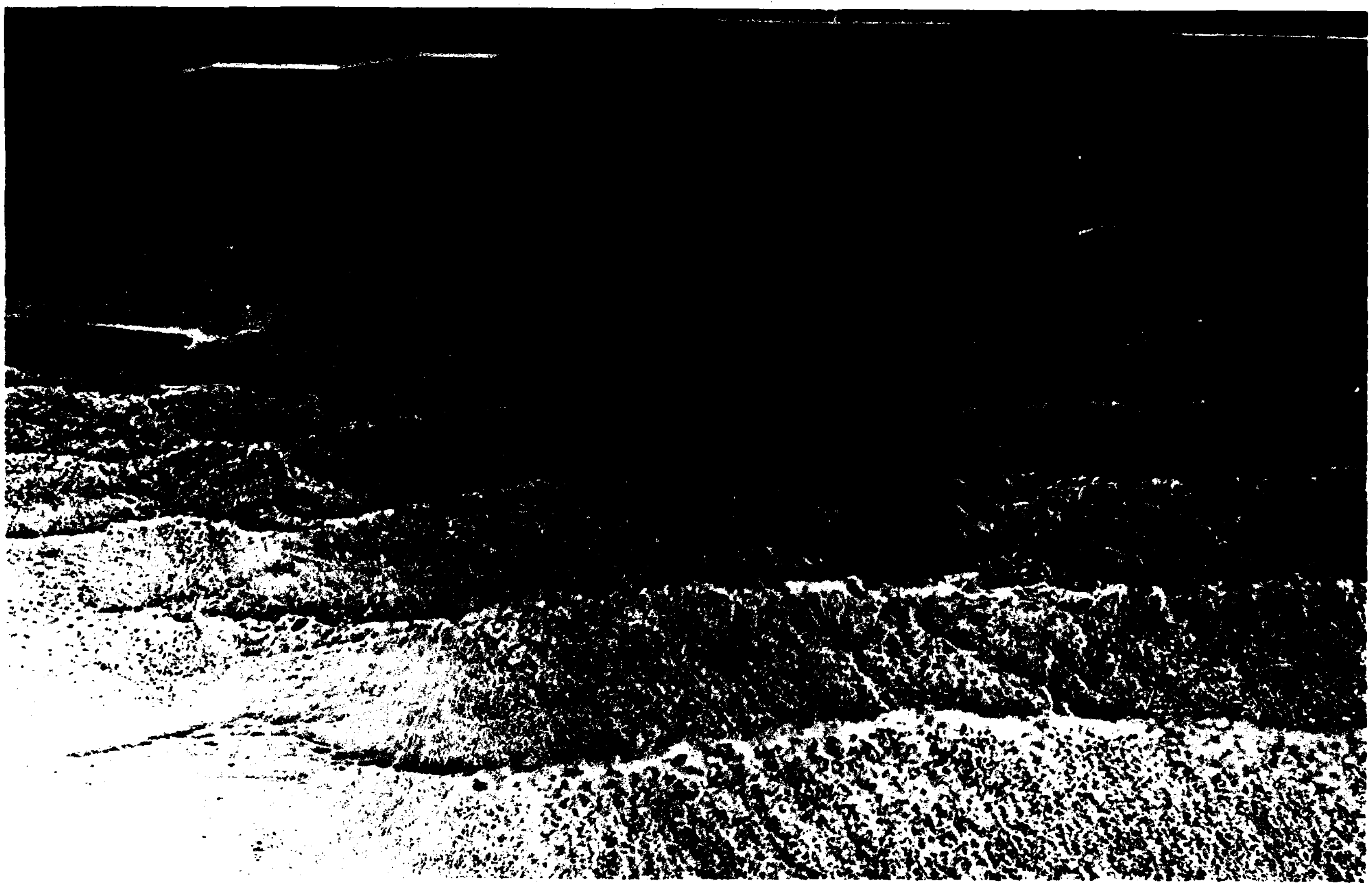


Photo 73. Typical wave patterns for Plan 6C; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 74. Typical wave patterns for Plan 7; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 75. Typical wave patterns for Plan 7A; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

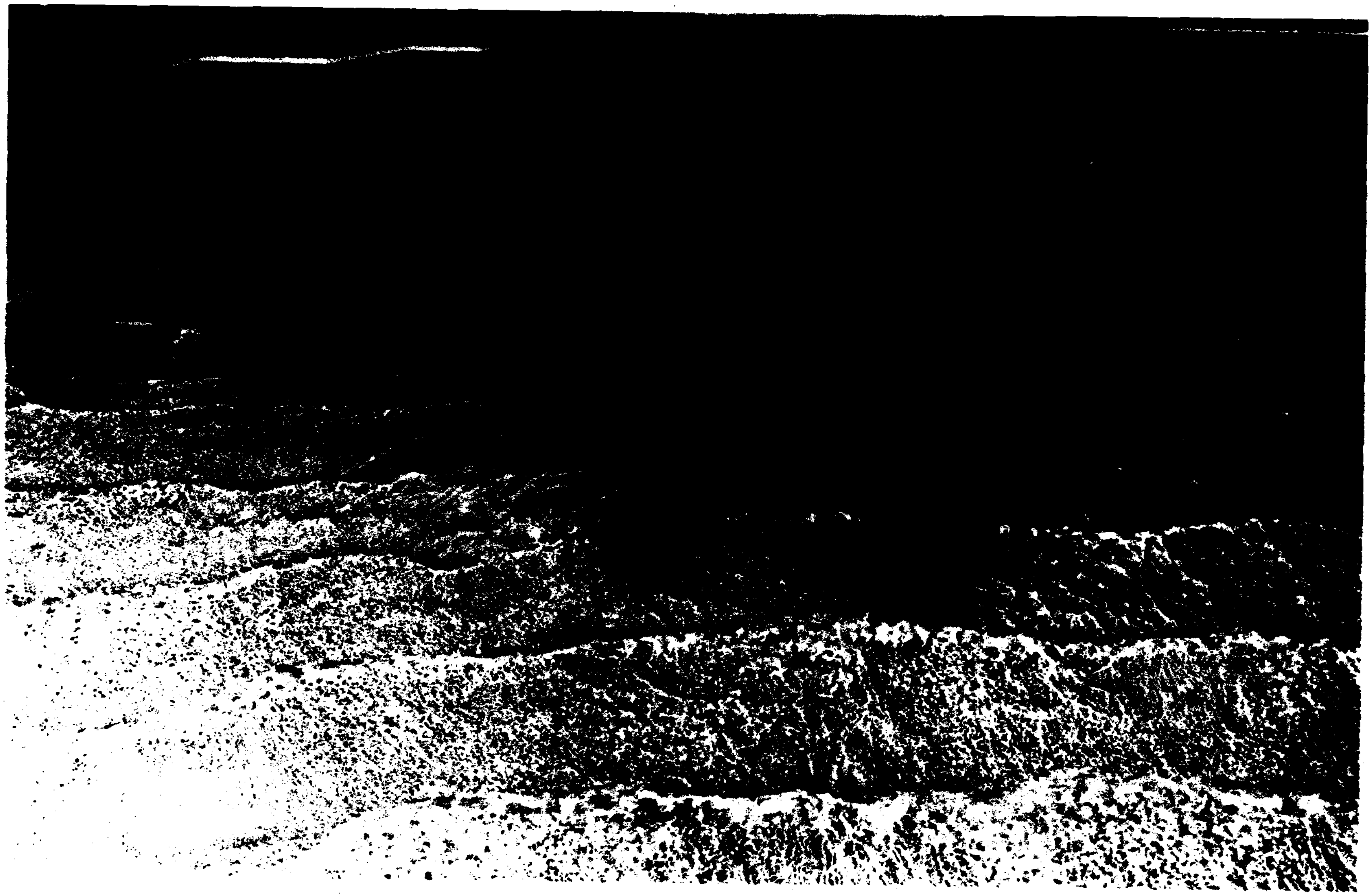


Photo 76. Typical wave patterns for Plan 7B; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 77. Typical wave patterns for Plan 7C; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

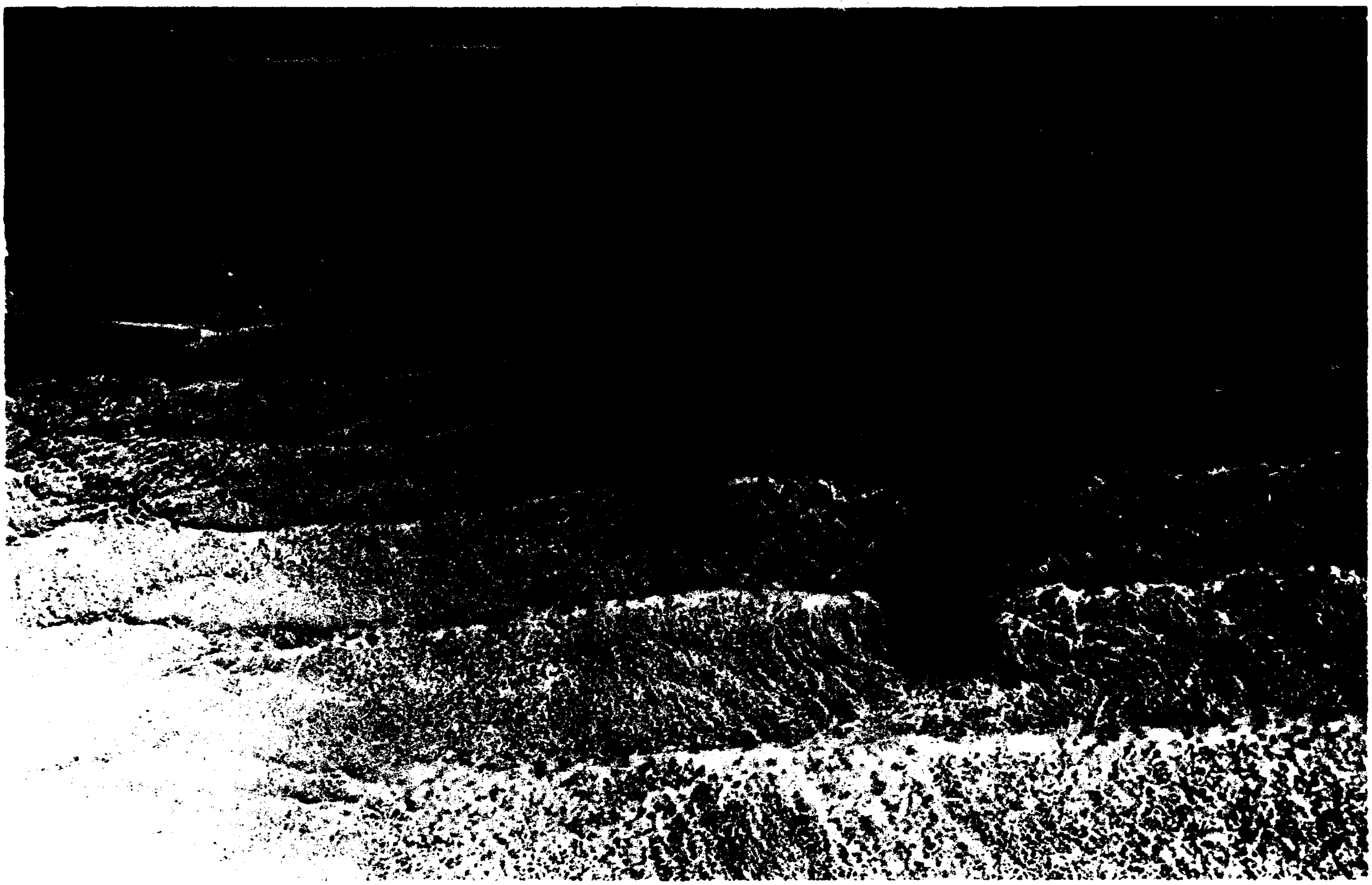


Photo 78. Typical wave patterns for Plan 7D; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

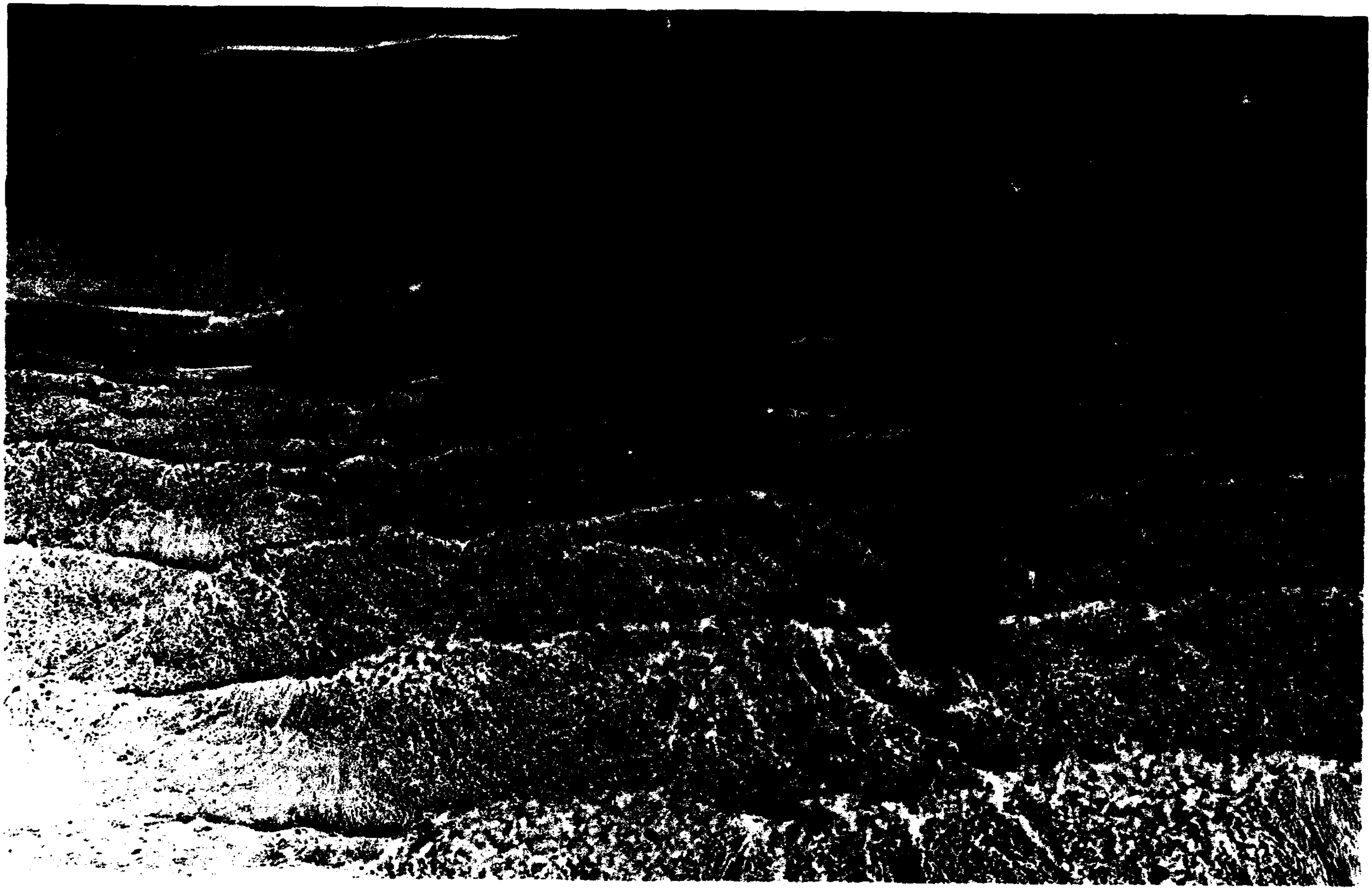


Photo 79. Typical wave patterns for Plan 7E; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

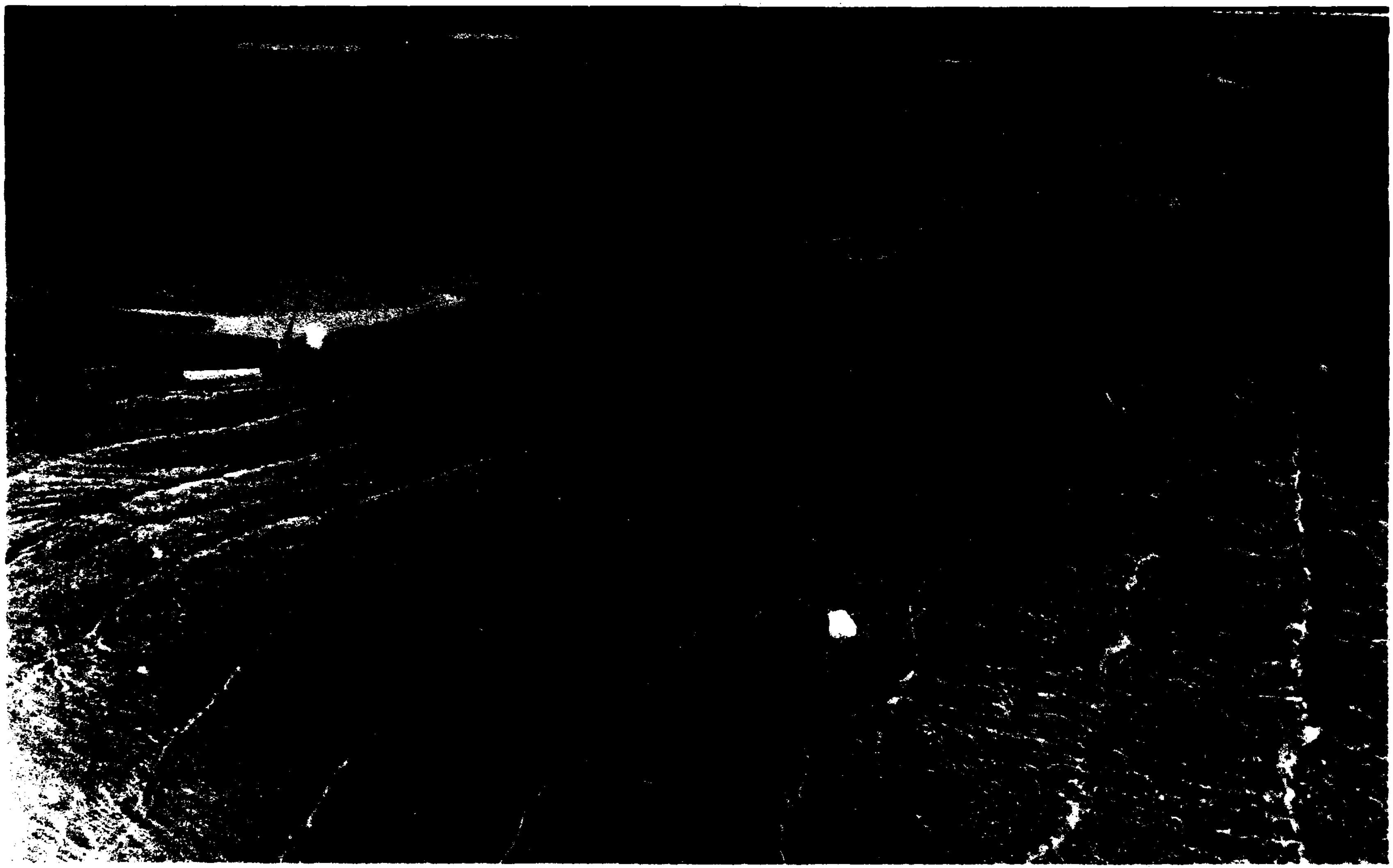


Photo 80. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 6.6-sec, 5.6-ft waves from 287 deg; +0.9 ft swl

Photo 81. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 9-sec, 10.9-ft waves from 287 deg; +0.9 ft swl

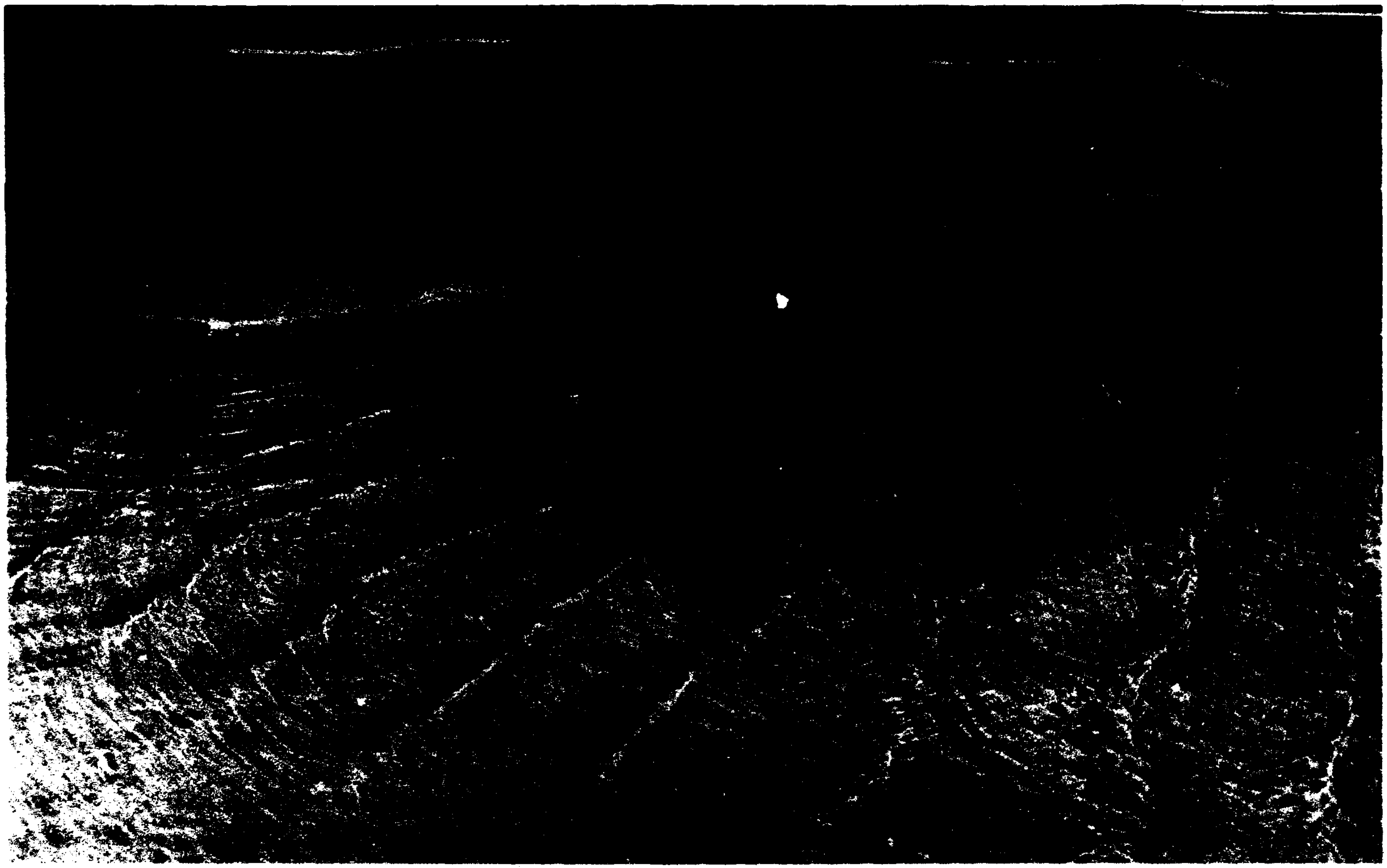


Photo 82. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 6.6-sec, 5.6-ft waves from 287 deg; +4.0 ft swl

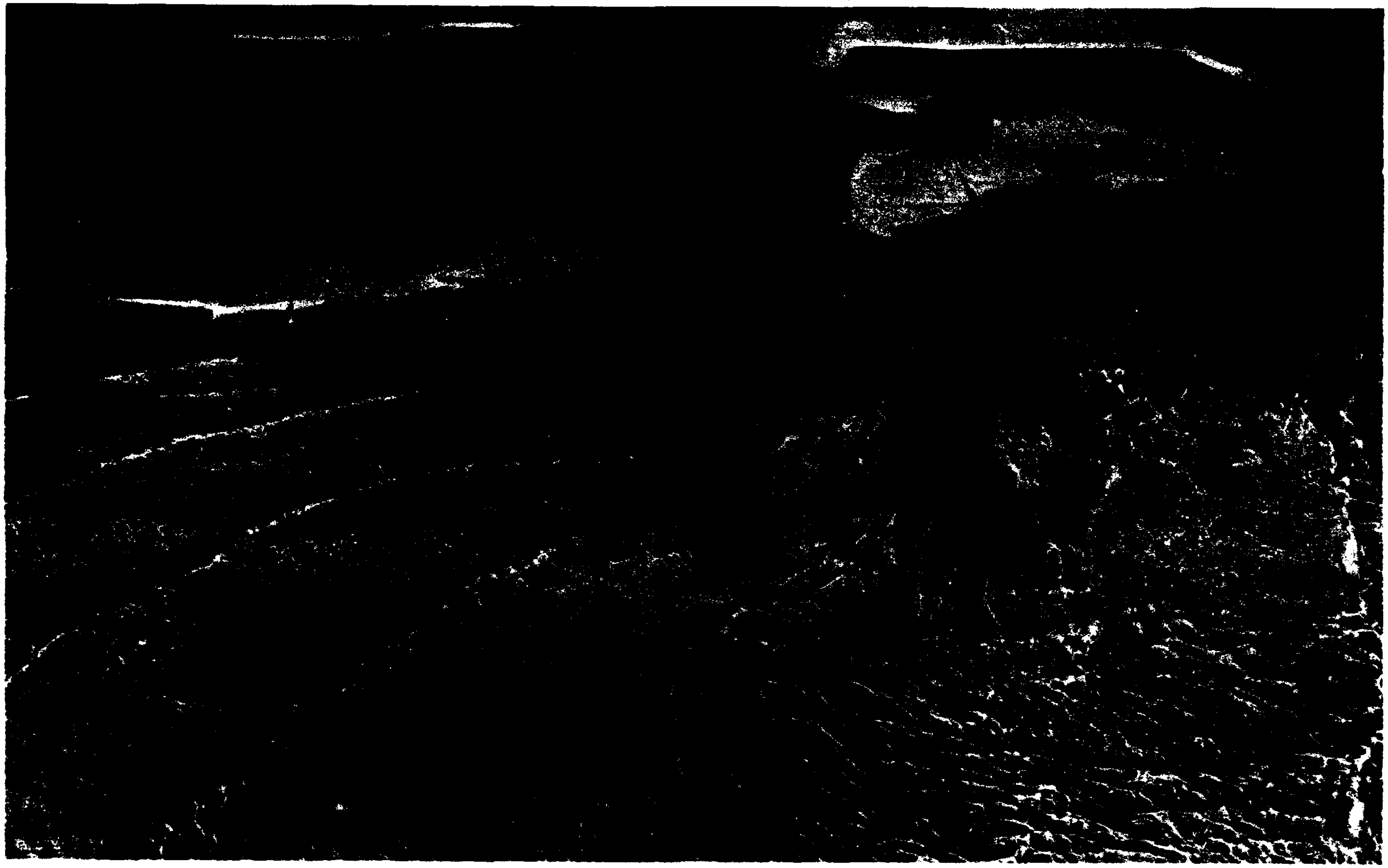


Photo 83. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 9-sec, 10.9-ft waves from 287 deg; +4.0 ft swl

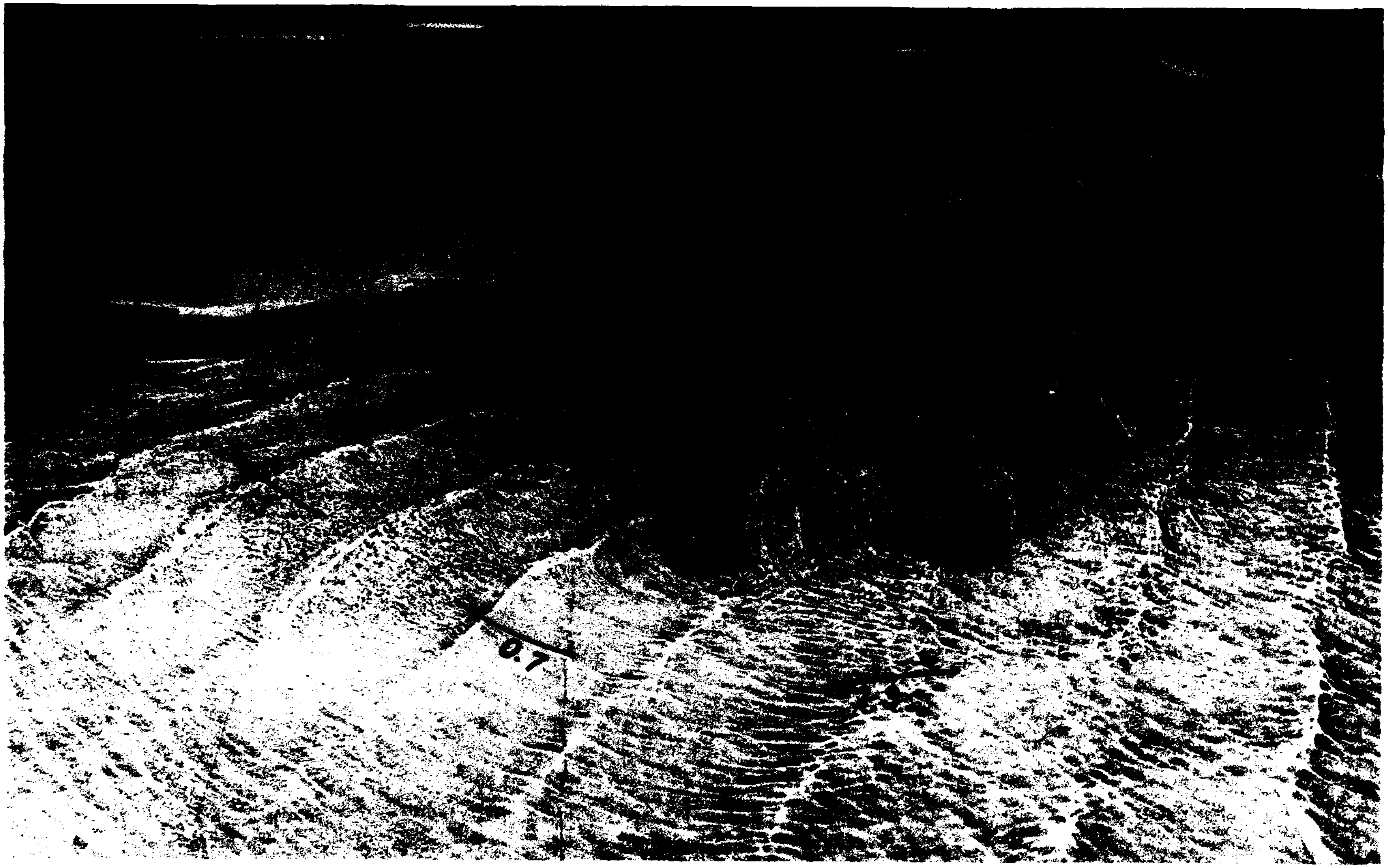


Photo 84. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 6.6-sec, 5.6-ft waves from 287 deg; +5.3 ft swl

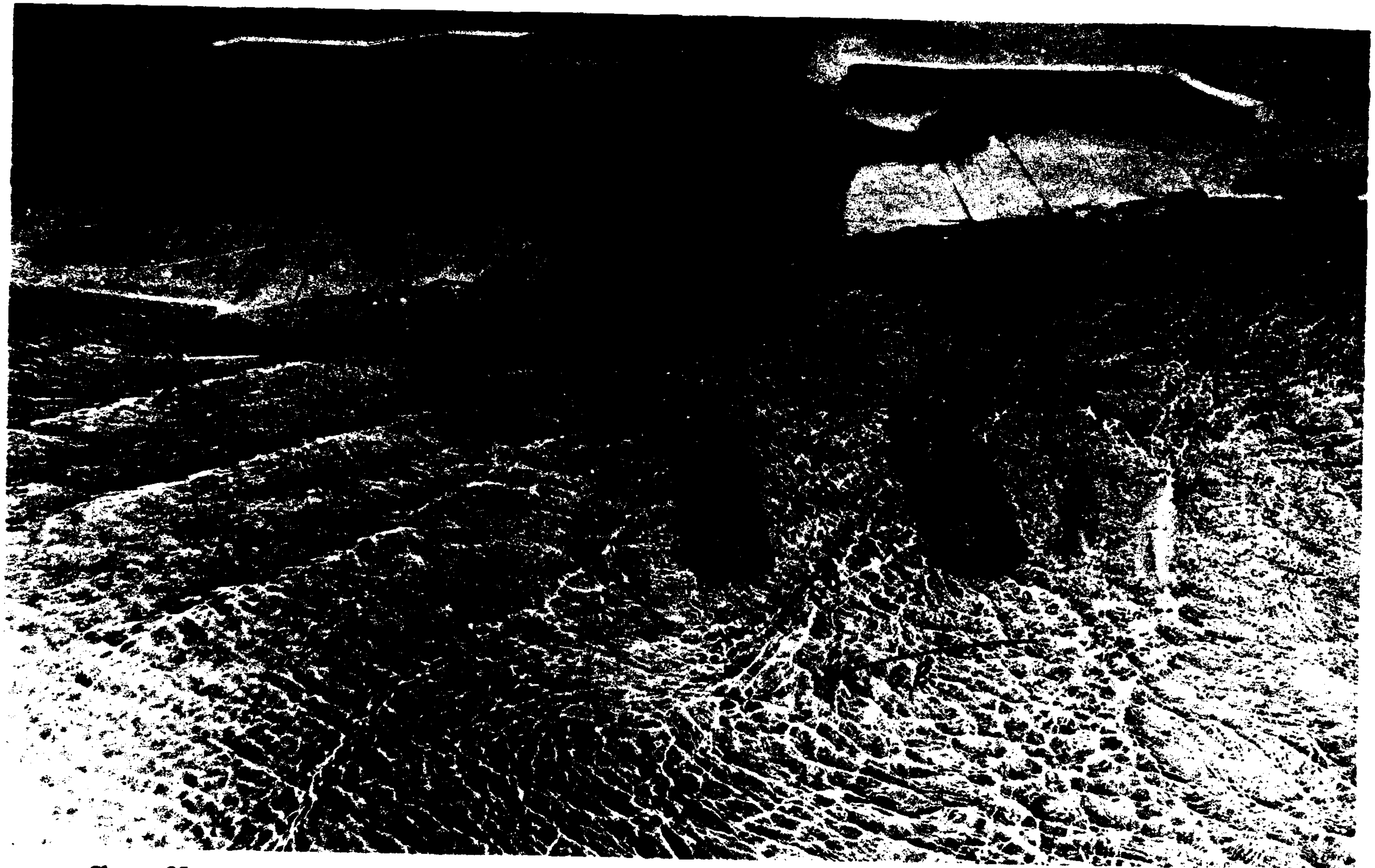


Photo 85. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second\` for Plan 2H; 9-sec, 10.9-ft waves from 287 deg; +5.3 ft swl

Photo 86. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 5.8-sec, 4.6-ft waves from 357 deg; +0.9 ft swl

Photo 87. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 7.8-sec, 10.9-ft waves from 357 deg; +0.9 ft swl

Photo 88. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 5.8-sec, 4.6-ft waves from 357 deg; +4.0 ft swl

Photo 89. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

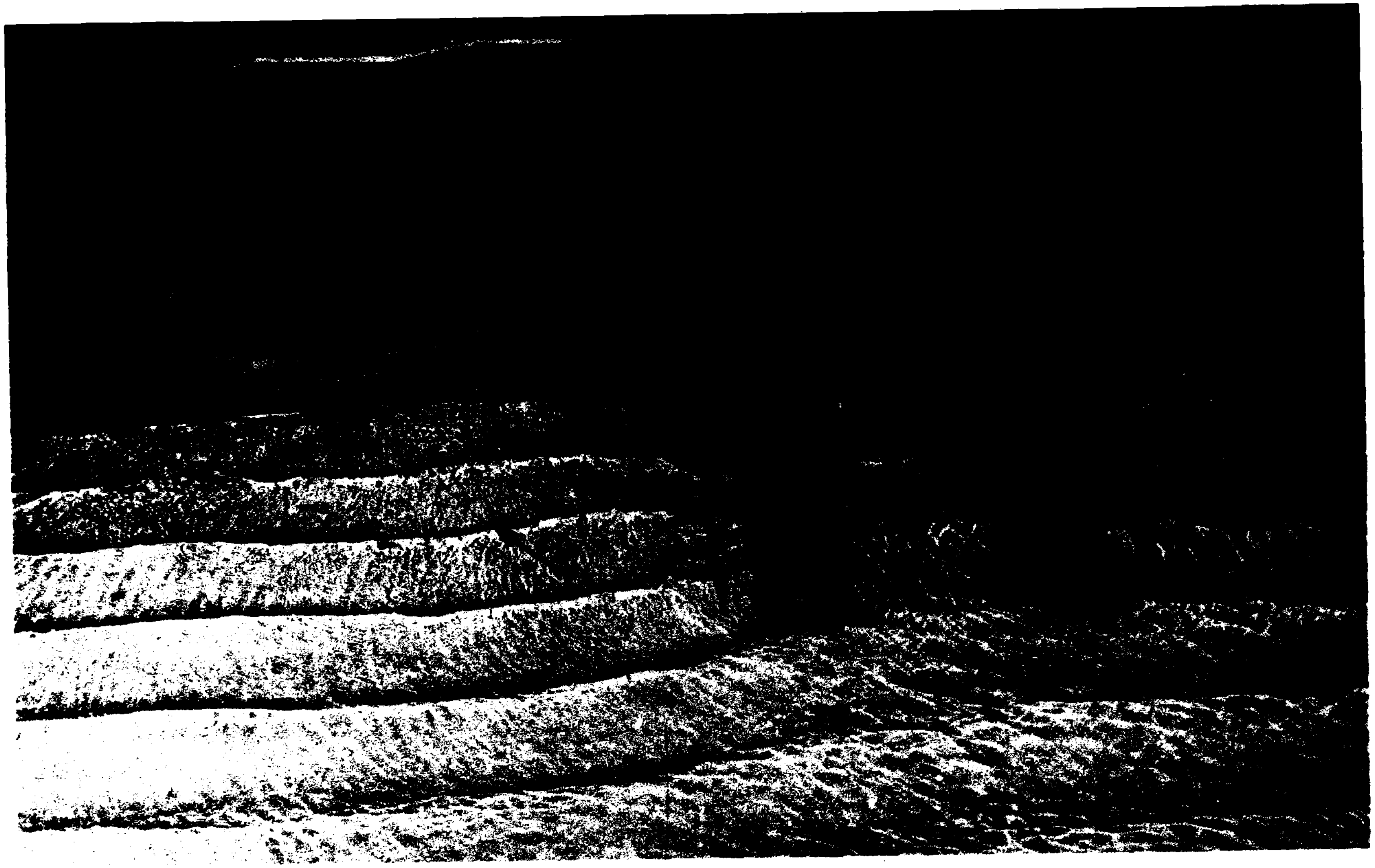


Photo 90. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 5.8-sec, 4.6-ft waves from 357 deg; +5.3 ft swl

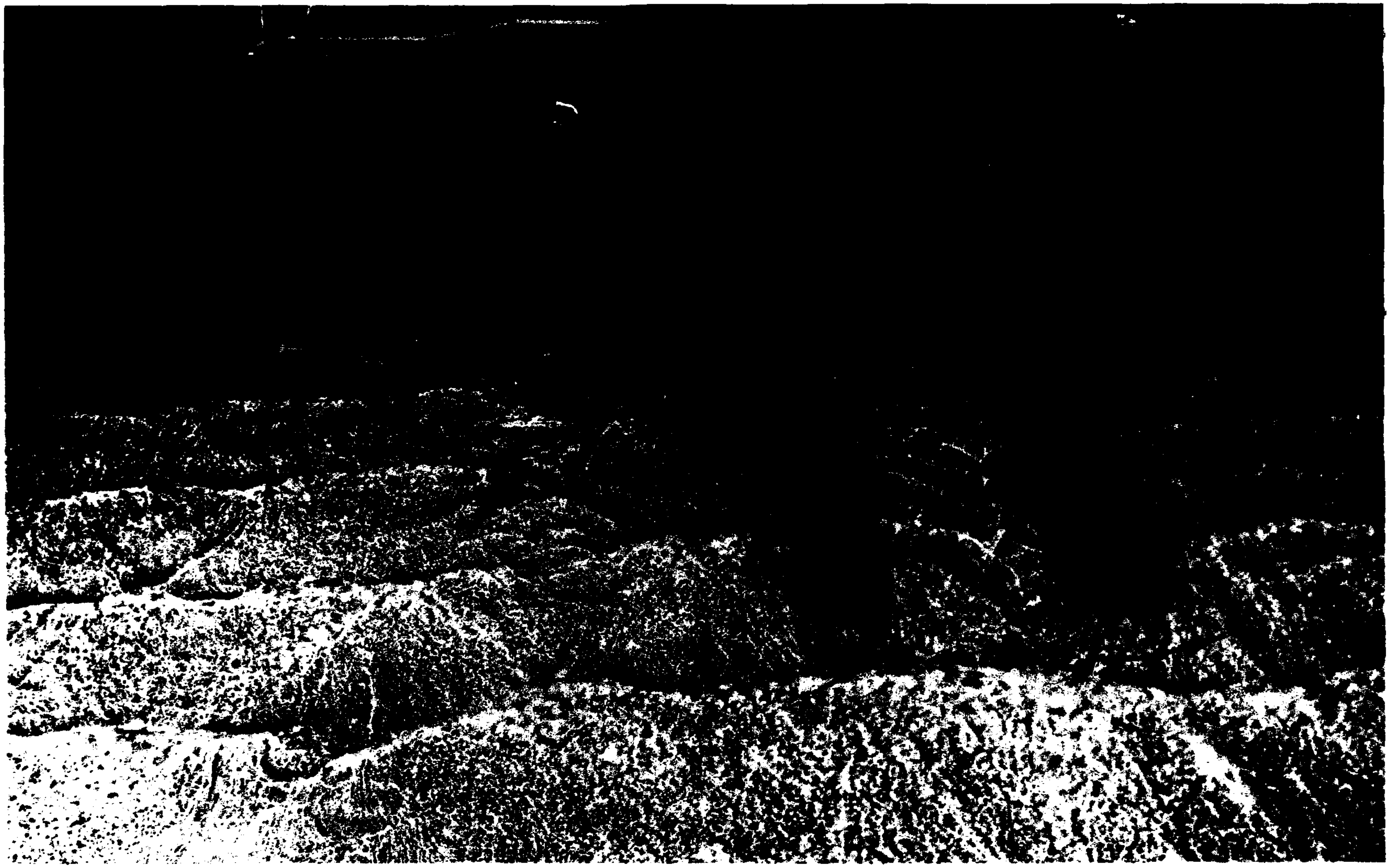


Photo 91. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 7.8-sec, 10.9-ft waves from 357 deg; +5.3 ft swl

Photo 92. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 6.2-sec, 6.3-ft waves from 19 deg; +0.9 ft swl

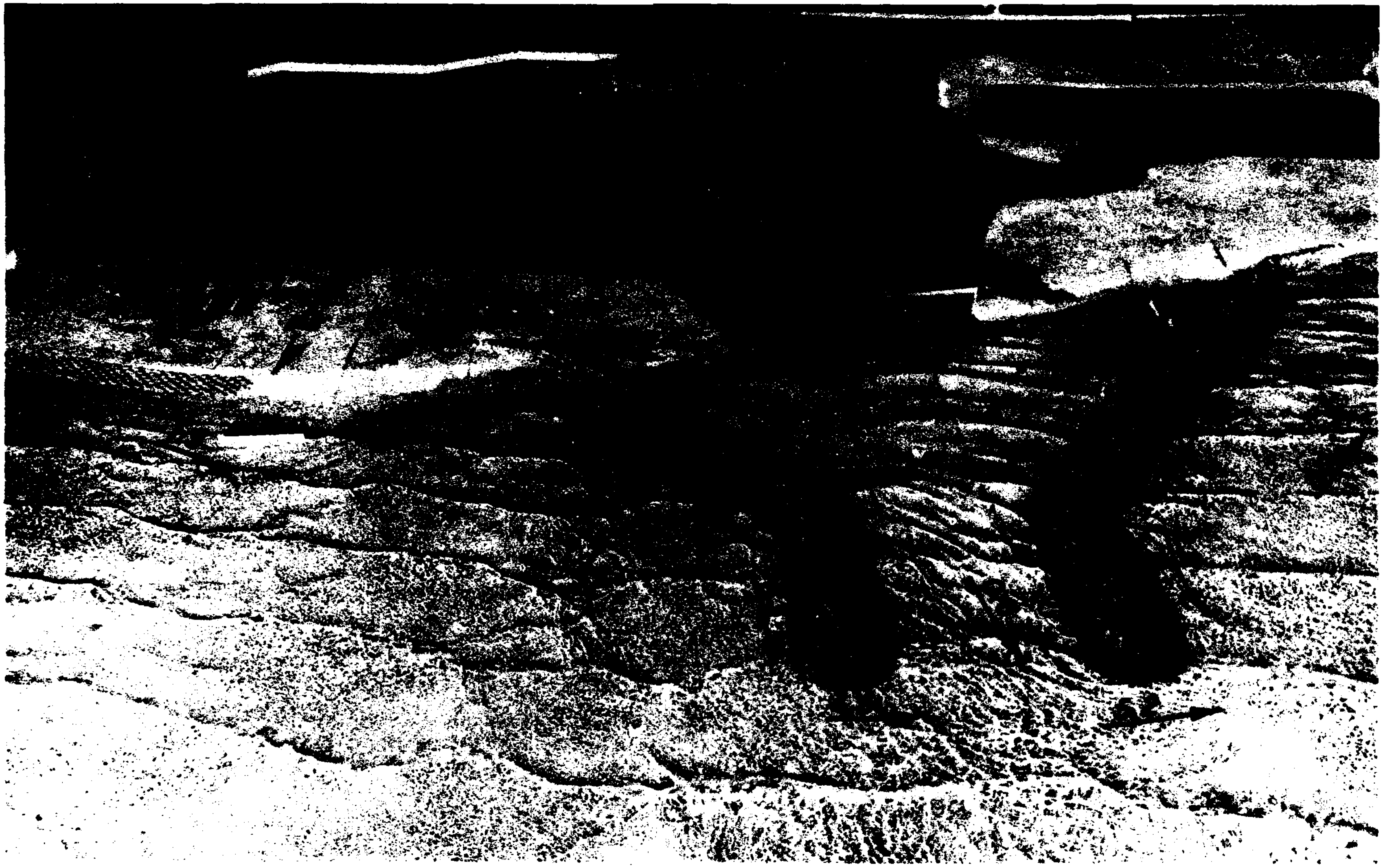


Photo 93. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 7.1-sec, 9.1-ft waves from 19 deg; +0.9 ft swl

Photo 94. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 6.2-sec, 6.3-ft waves from 19 deg; +4.0 ft swl

Photo 95. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 7.1-sec, 9.1-ft waves from 19 deg; +4.0 ft swl

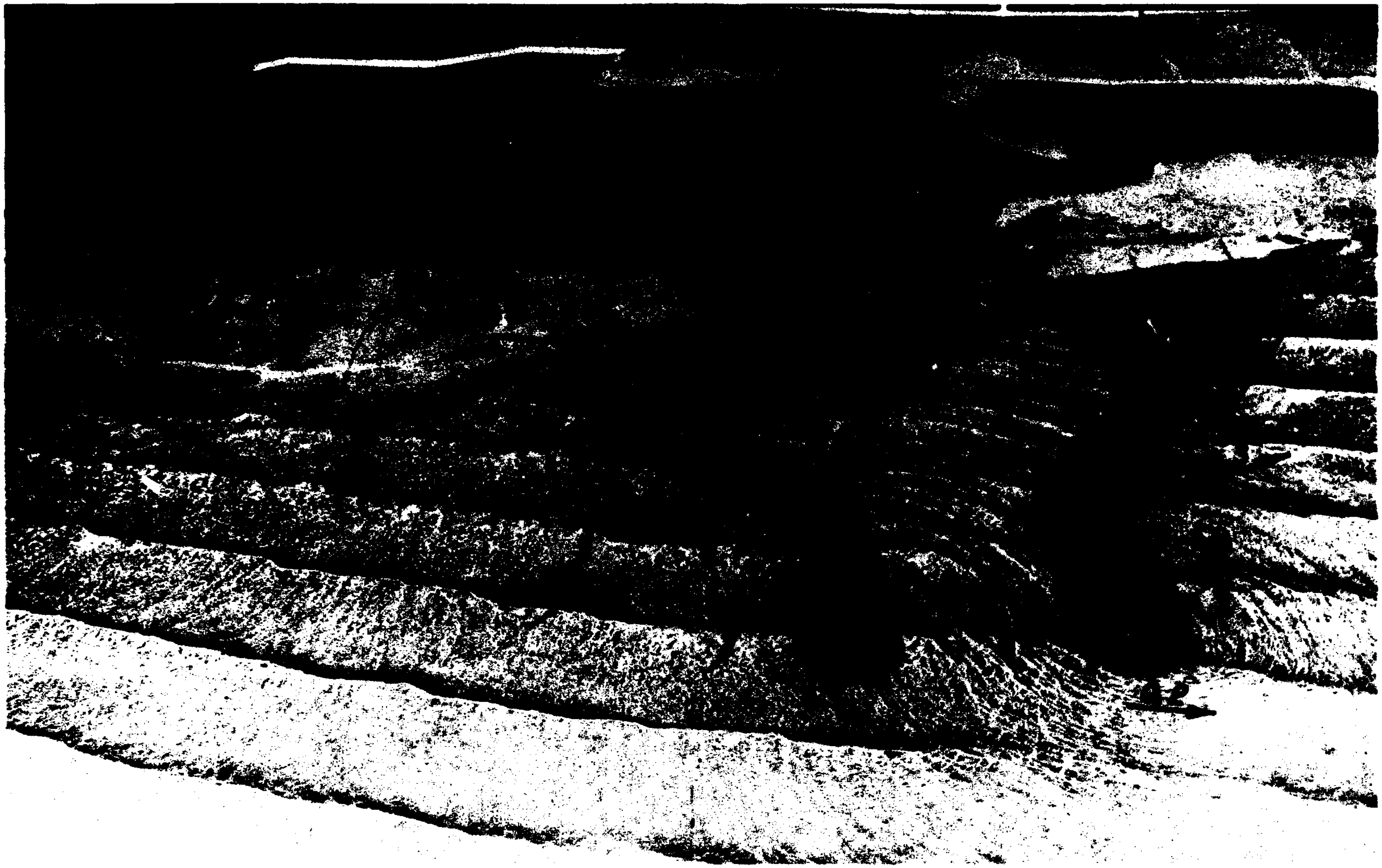


Photo 96. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 6.2-sec, 6.3-ft waves from 19 deg; +5.3 ft swl

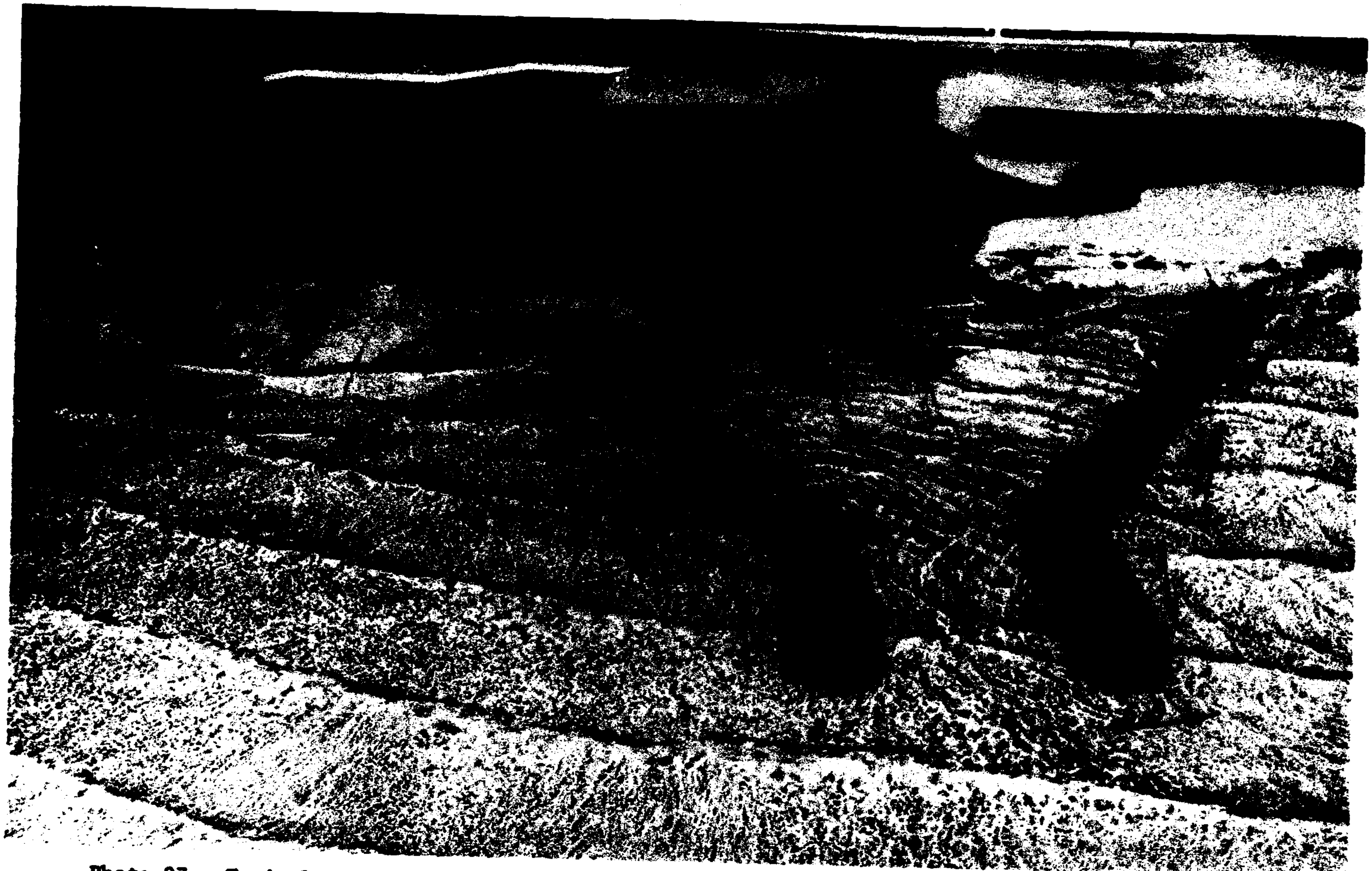


Photo 97. Typical wave patterns, current patterns, and current magnitudes (prototype feet per second) for Plan 2H; 7.1-sec, 9.1-ft waves from 19 deg; +5.3 ft swl

Photo 98. General movement of tracer material for Plan 2H; 6.6-sec, 5.6-ft waves from 287 deg; +0.9 ft swl

Photo 99. General movement of tracer material for Plan 2H; 9-sec, 10.9-ft waves from 287 deg; +0.9 ft swl

Photo 100. General movement of tracer material for Plan 2H; 6.6-sec, 5.6-ft waves from 287 deg; +4.0 ft swl

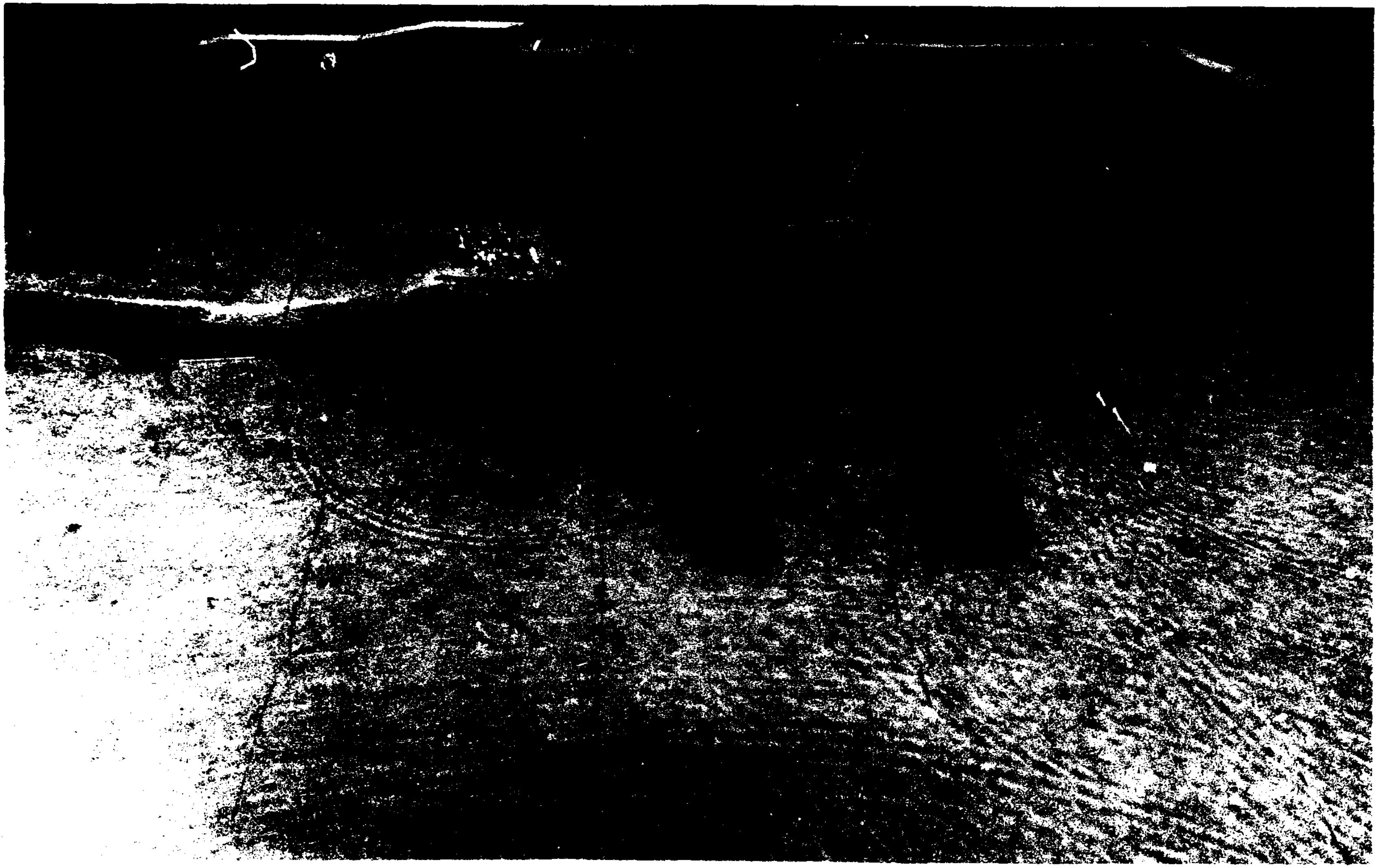


Photo 101. General movement of tracer material for Plan 2H; 9-sec, 10.9-ft waves from 287 deg; +4.0 ft swl

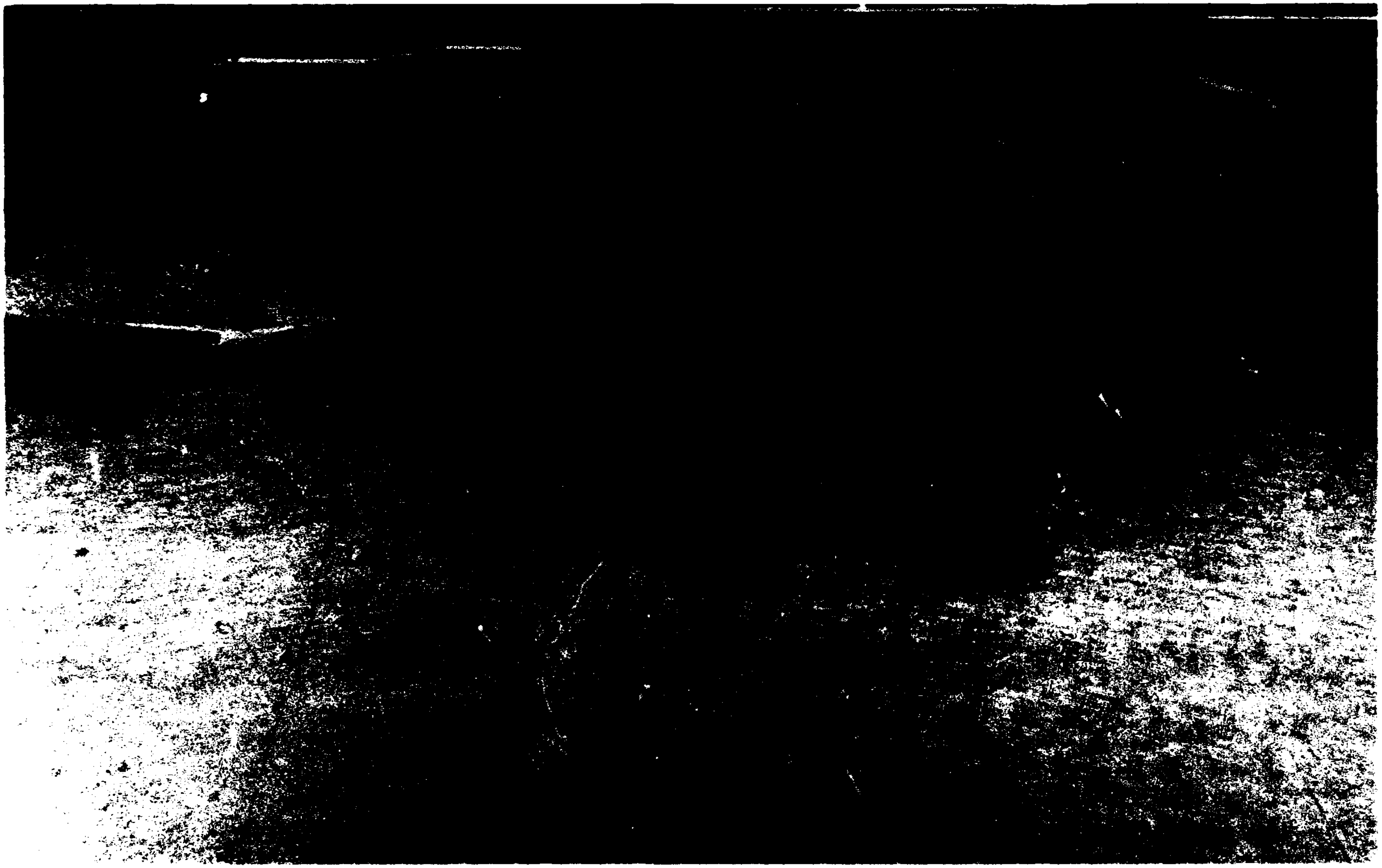


Photo 102. General movement of tracer material for Plan 2H; 6.6-sec, 5.6-ft waves from 287 deg; +5.3 ft swl

Photo 103. General movement of tracer material for Plan 2H; 9-sec, 10.9-ft waves from 287 deg; +5.3 ft swl

Photo 104. General movement of tracer material for Plan 2H; 5.8-sec, 4.6-ft waves from 357 deg; +0.9 ft swl

Photo 105. General movement of tracer material for Plan 2H; 7.8-sec, 10.9-ft waves from 357 deg; +0.9 ft swl

Photo 106. General movement of tracer material for Plan 2H; 5.8-sec, 4.6-ft waves from 357 deg; +4.0 ft swl

Photo 107. General movement of tracer material for Plan 2H; 7.8-sec, 10.9-ft waves from 357 deg; +4.0 ft swl

Photo 108. General movement of tracer material for Plan 2H; 5.8-sec, 4.6-ft waves from 357 deg; +5.3 ft swl

Photo 109. General movement of tracer material for Plan 2H; 7.8-sec, 10.9-ft waves from 357 deg; +5.3 ft swl

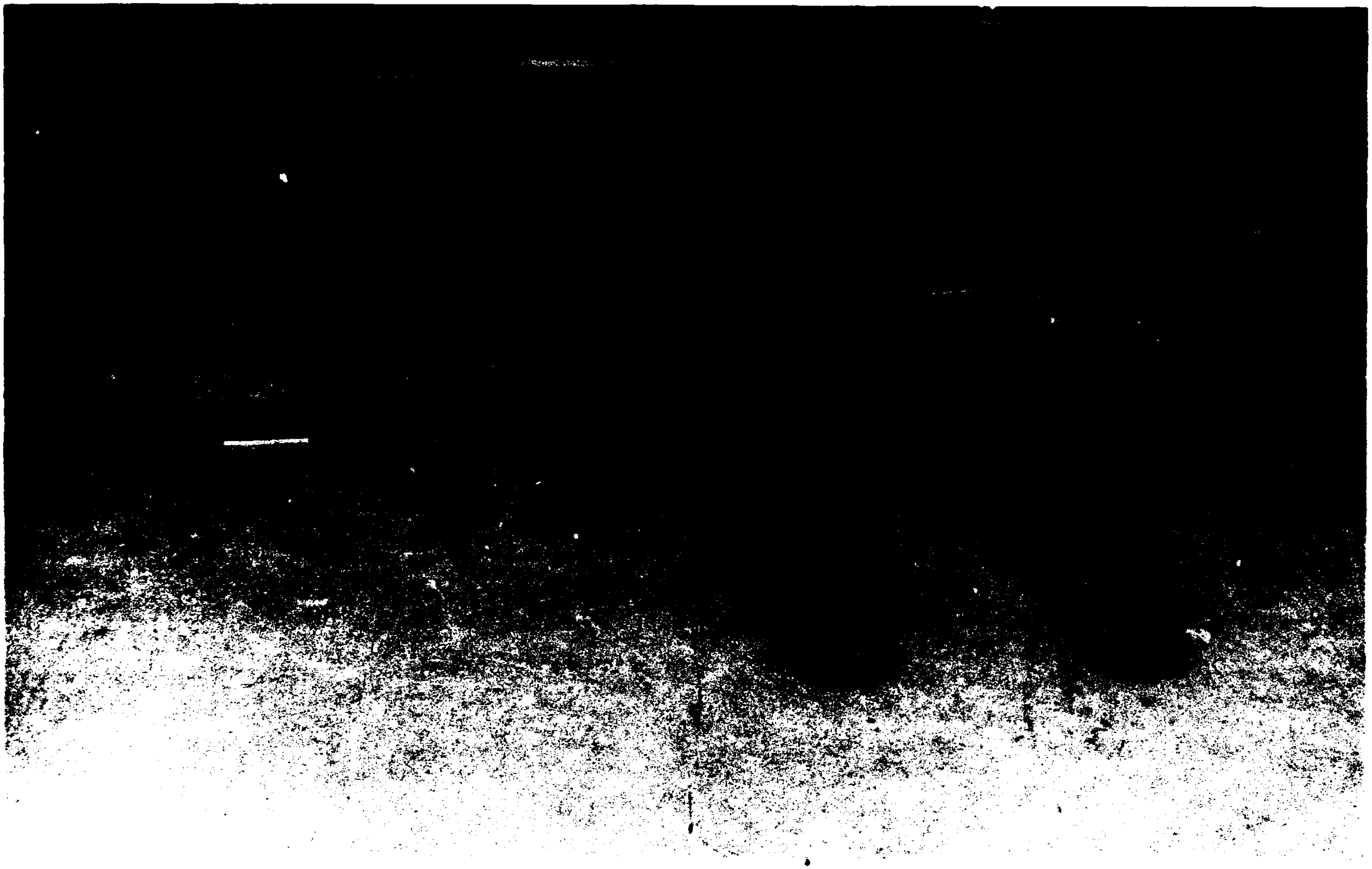


Photo 110. General movement of tracer material for Plan 2H; 6.2-sec, 6.3-ft waves from 19 deg; +0.9 ft swl

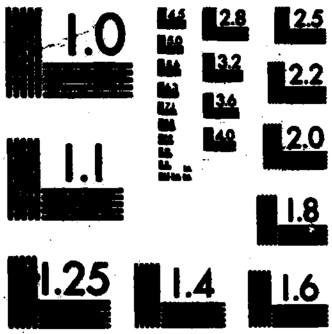
Photo 111. General movement of tracer material for Plan 2H; 7.1-sec, 9.1-ft waves from 19 deg; +0.9 ft swl

Photo 112. General movement of tracer material for Plan 2H; 6.2-sec, 6.3-ft waves from 19 deg; +4.0 ft swl

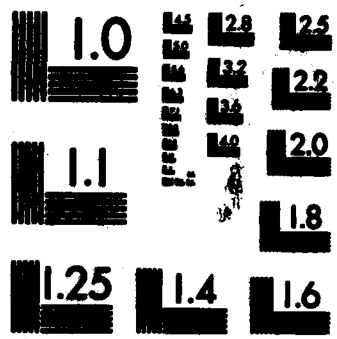
Photo 113. General movement of tracer material for Plan 2H; 7.1-sec, 9.1-ft waves from 19 deg; +4.0 ft swl

AD-A120 823 DESIGN FOR WAVE PROTECTION AND PREVENTION OF SHOALING GENEVA-ON-THE-LAKE..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. R R BOTTIN 3/3

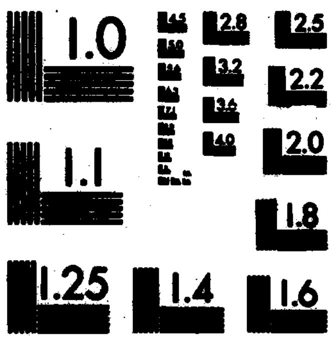
UNCLASSIFIED AUG 82 WES/TR/HL-82-17 F/G 13/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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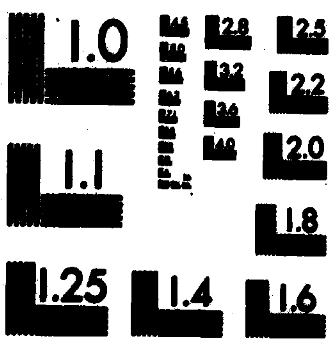
NATIONAL BUREAU OF STANDARDS-1963-A



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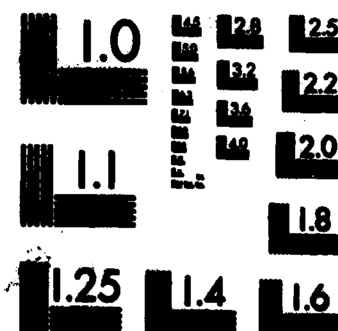
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Photo 114. General movement of tracer material for Plan 2H; 6.2-sec, 6.3-ft waves from 19 deg; +5.3 ft swl

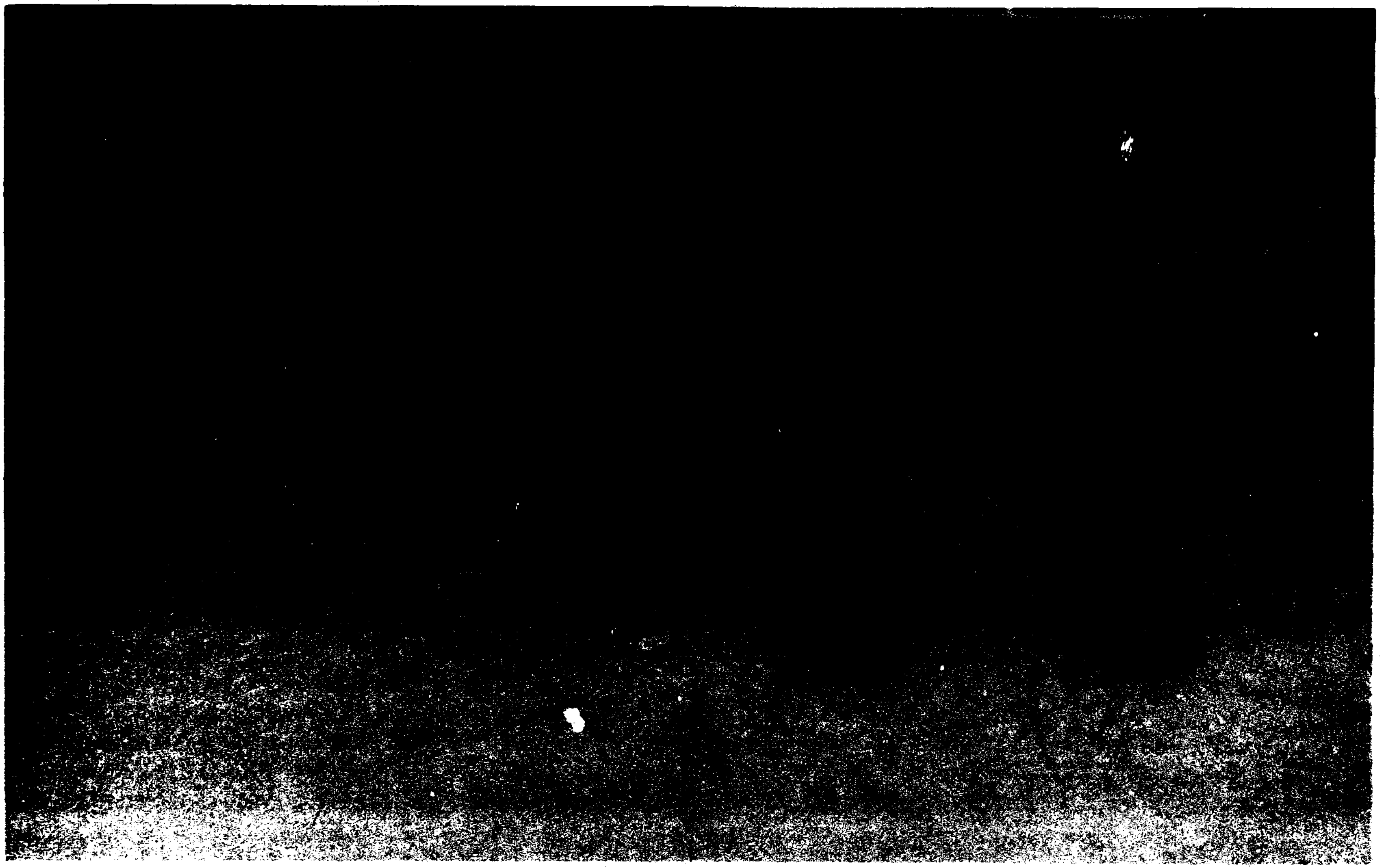


Photo 115. General movement of tracer material for Plan 2H; 7.1-sec, 9.1-ft waves from 19 deg; +5.3 ft swl

Photo 1 Velocities in the wetland area due to lowering the water level by means of the control structure

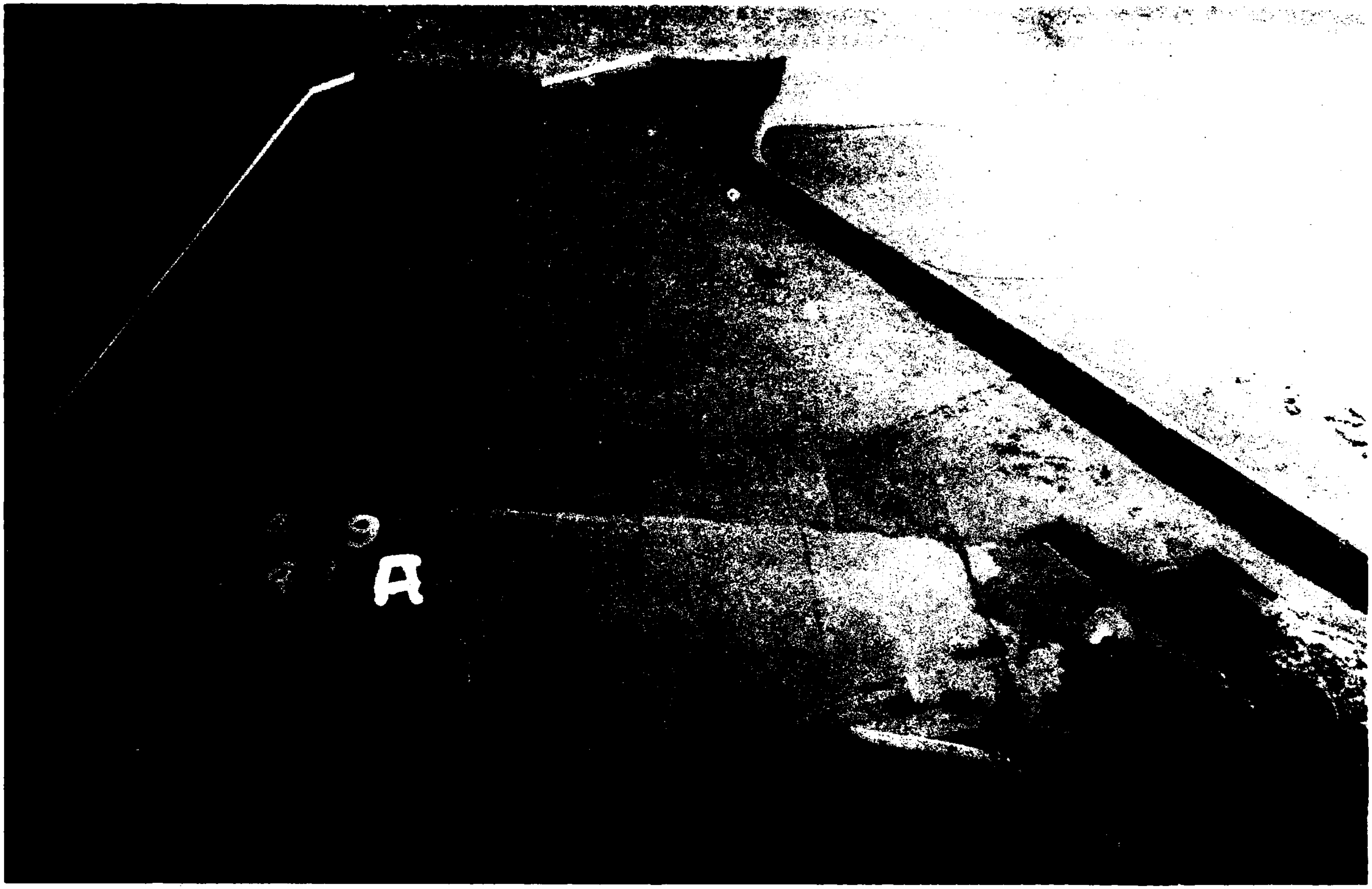


Photo 117. Model cabin cruiser entering harbor (en route to center of east wall)

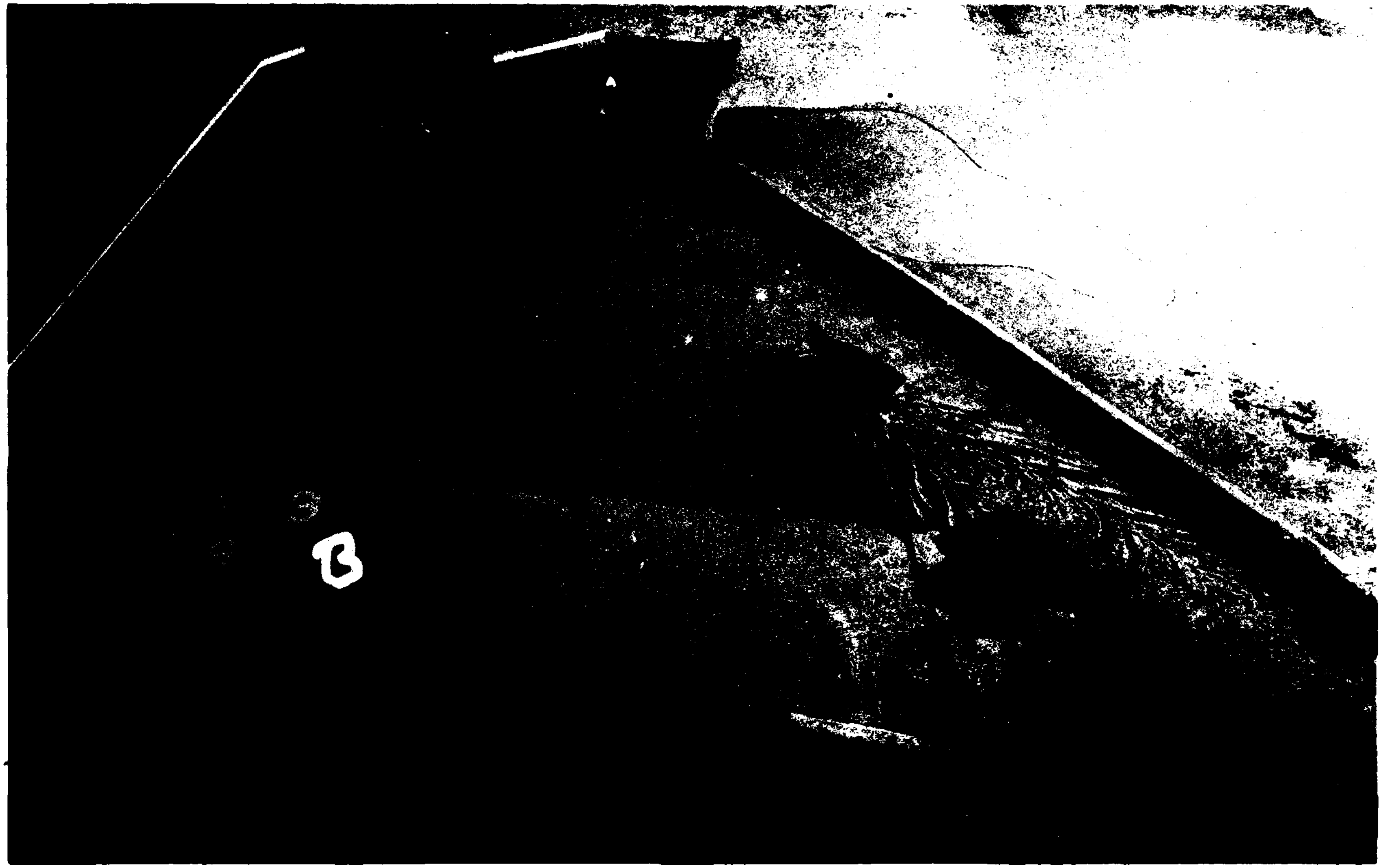


Photo 118. Location of model cabin cruiser and wave formations 3 sec after the vessel entered harbor (en route to center of east wall)

Photo 119. Location of model cabin cruiser and wave formations 6 sec after the vessel entered harbor (en route to center of east wall)

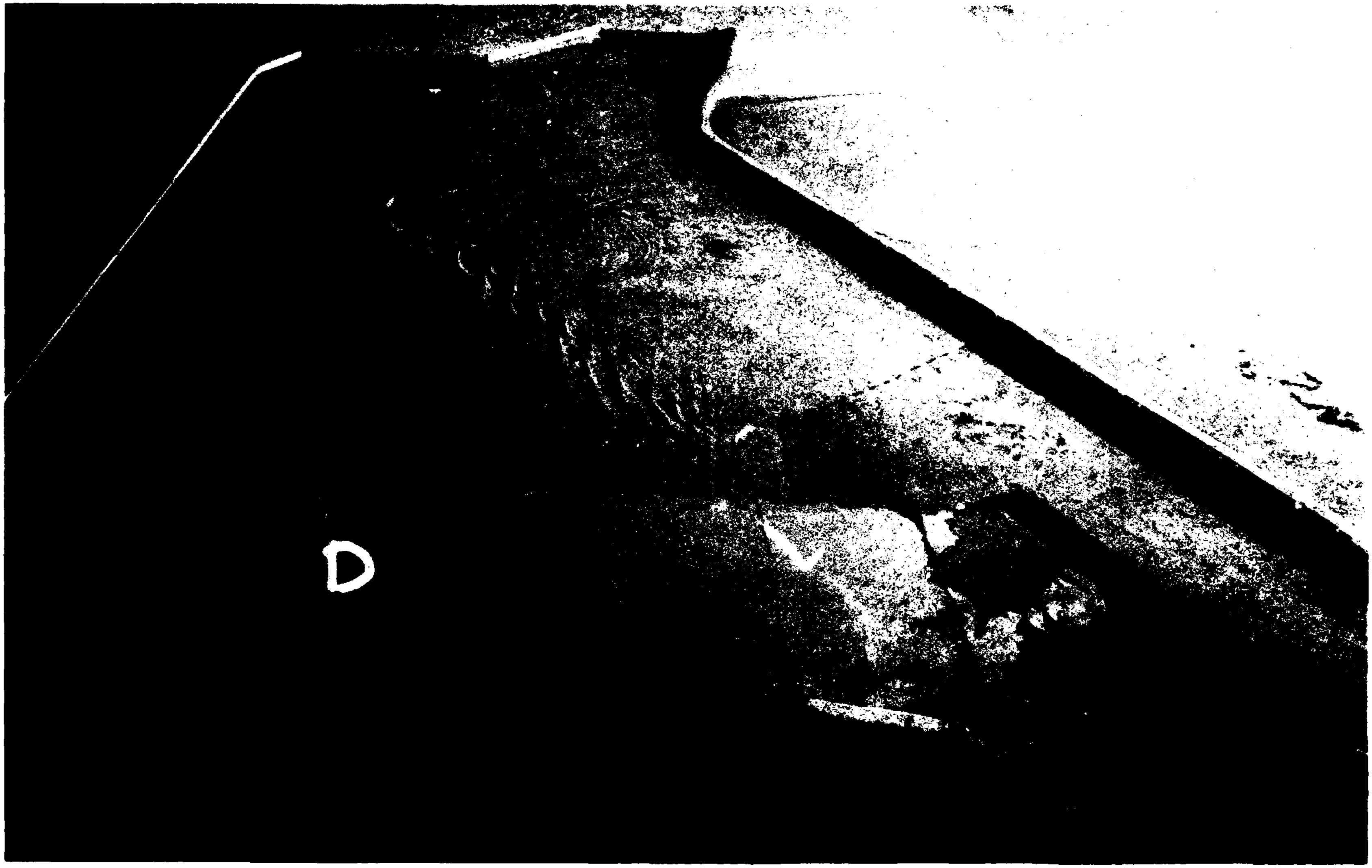


Photo 120. Location of model cabin cruiser and wave formations 9 sec after the vessel entered harbor (en route to center of east wall)

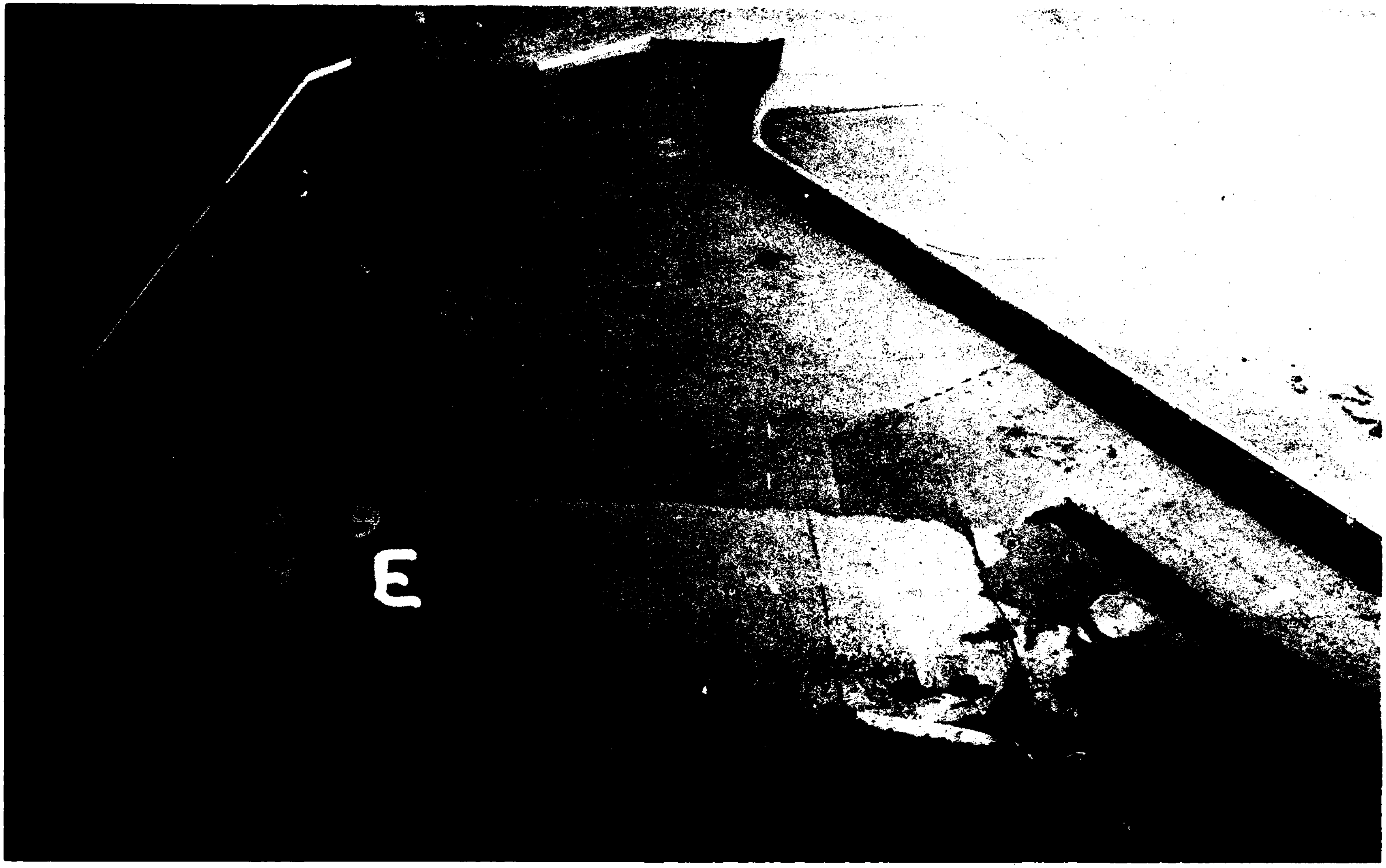


Photo 121. Location of model cabin cruiser and wave formations 12 sec after the vessel entered harbor (en route to center of east wall)

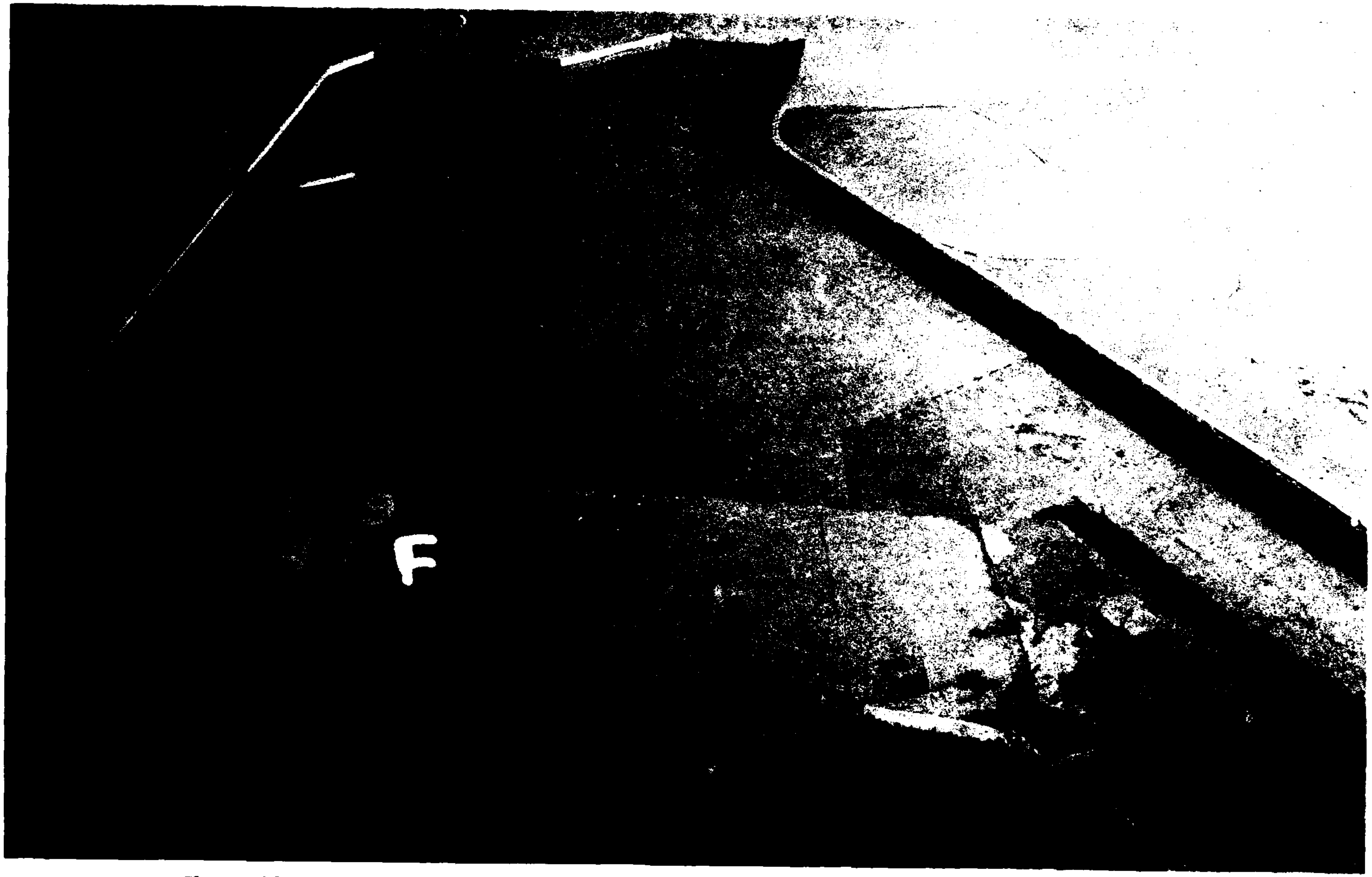


Photo 122. Wave patterns in the harbor due to boat wake 15 sec after the vessel entered harbor (en route to center of east wall)

Photo 123. Wave patterns in the harbor due to boat wake 18 sec after the vessel entered harbor (en route to center of east wall)

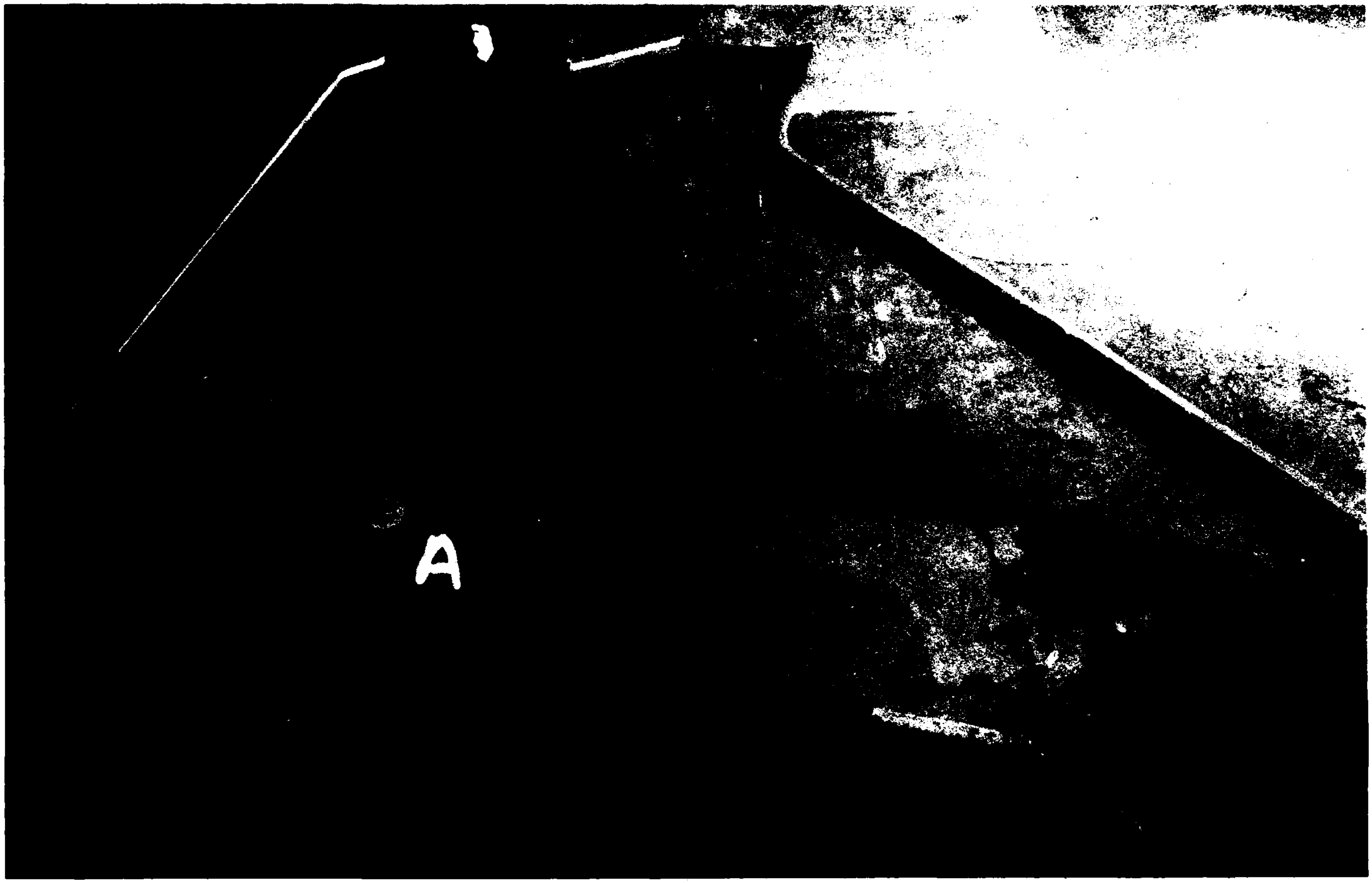


Photo 124. Model cabin cruiser preparing to leave harbor (from northeast corner)

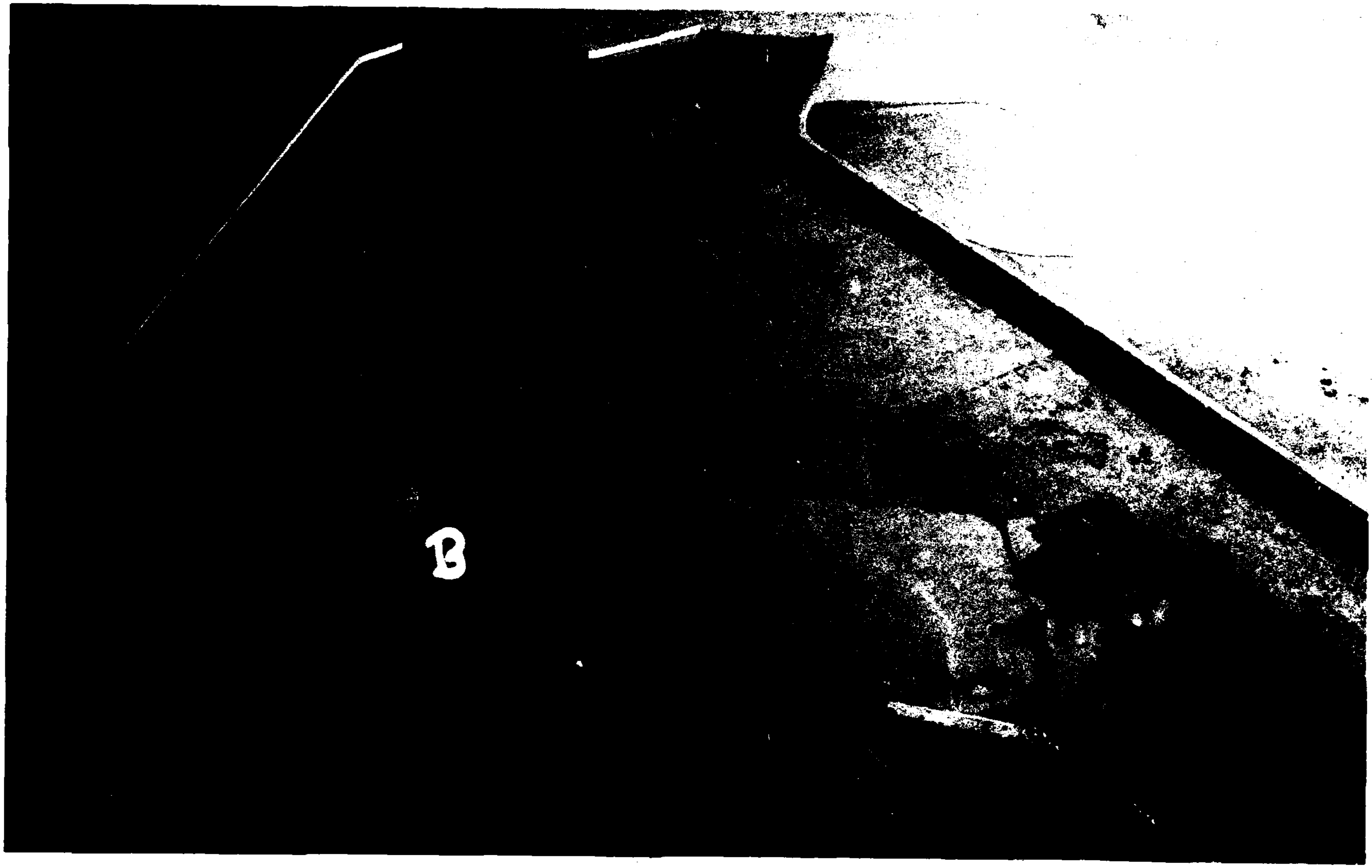


Photo 125. Location of model cabin cruiser and wave formations 3 sec after the vessel began acceleration (leaving from northeast corner)

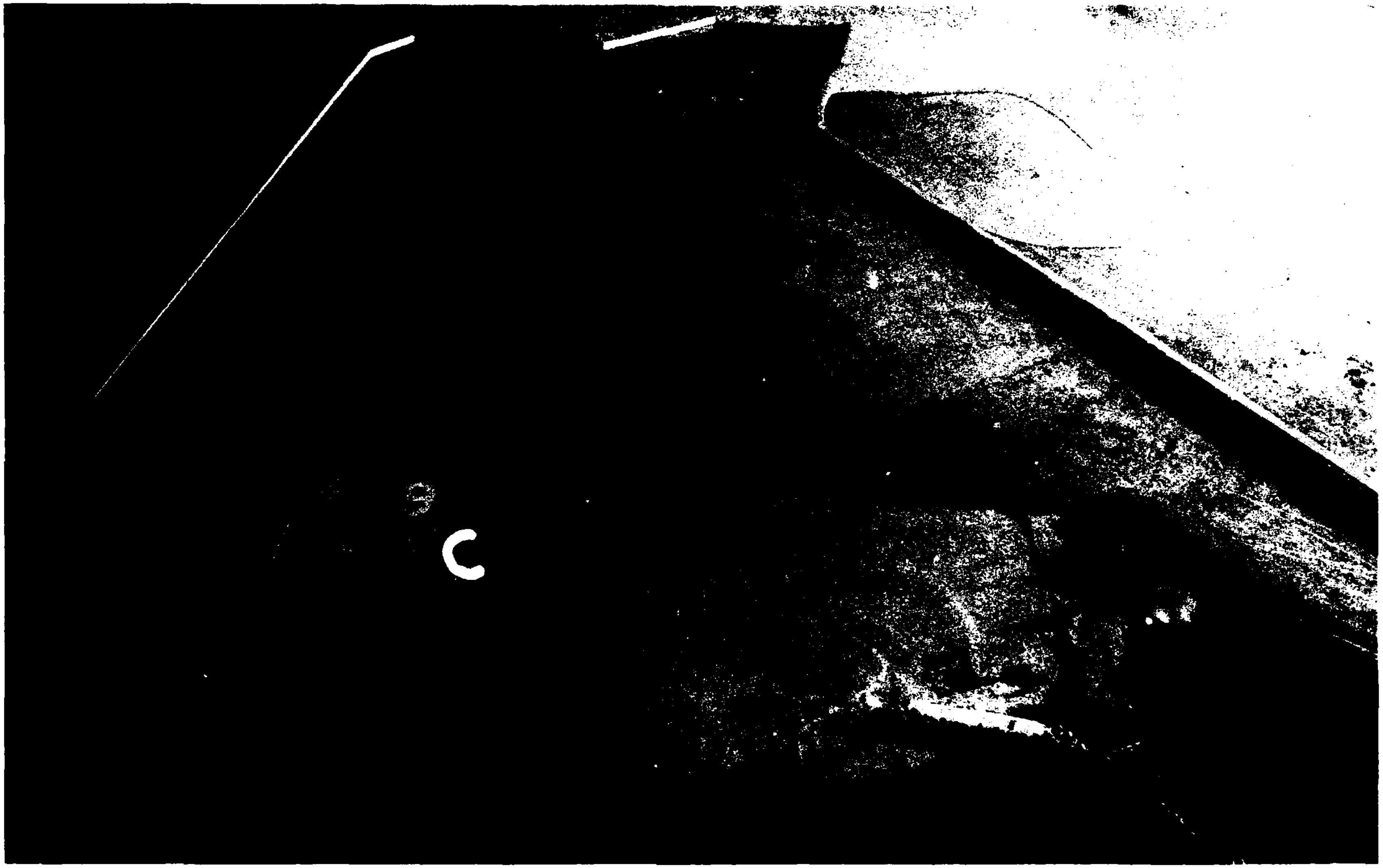


Photo 126. Location of model cabin cruiser and wave formations 6 sec after the vessel began acceleration (leaving from northeast corner)

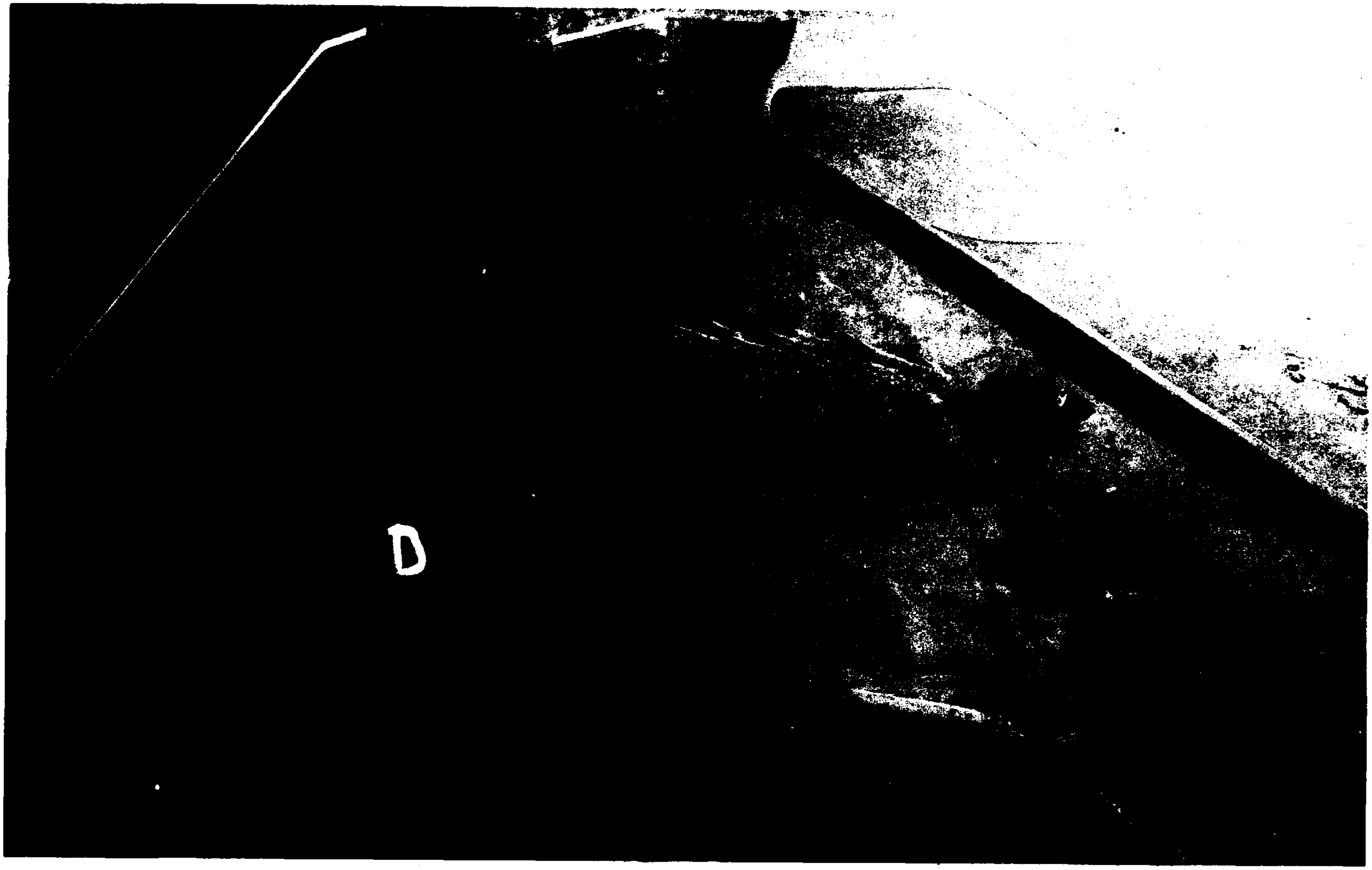


Photo 127. Location of model cabin cruiser and wave formations 9 sec after the vessel began acceleration (leaving from northeast corner)

Photo 128. Location of model cabin cruiser and wave formations 12 sec after the vessel began acceleration (leaving from northeast corner)

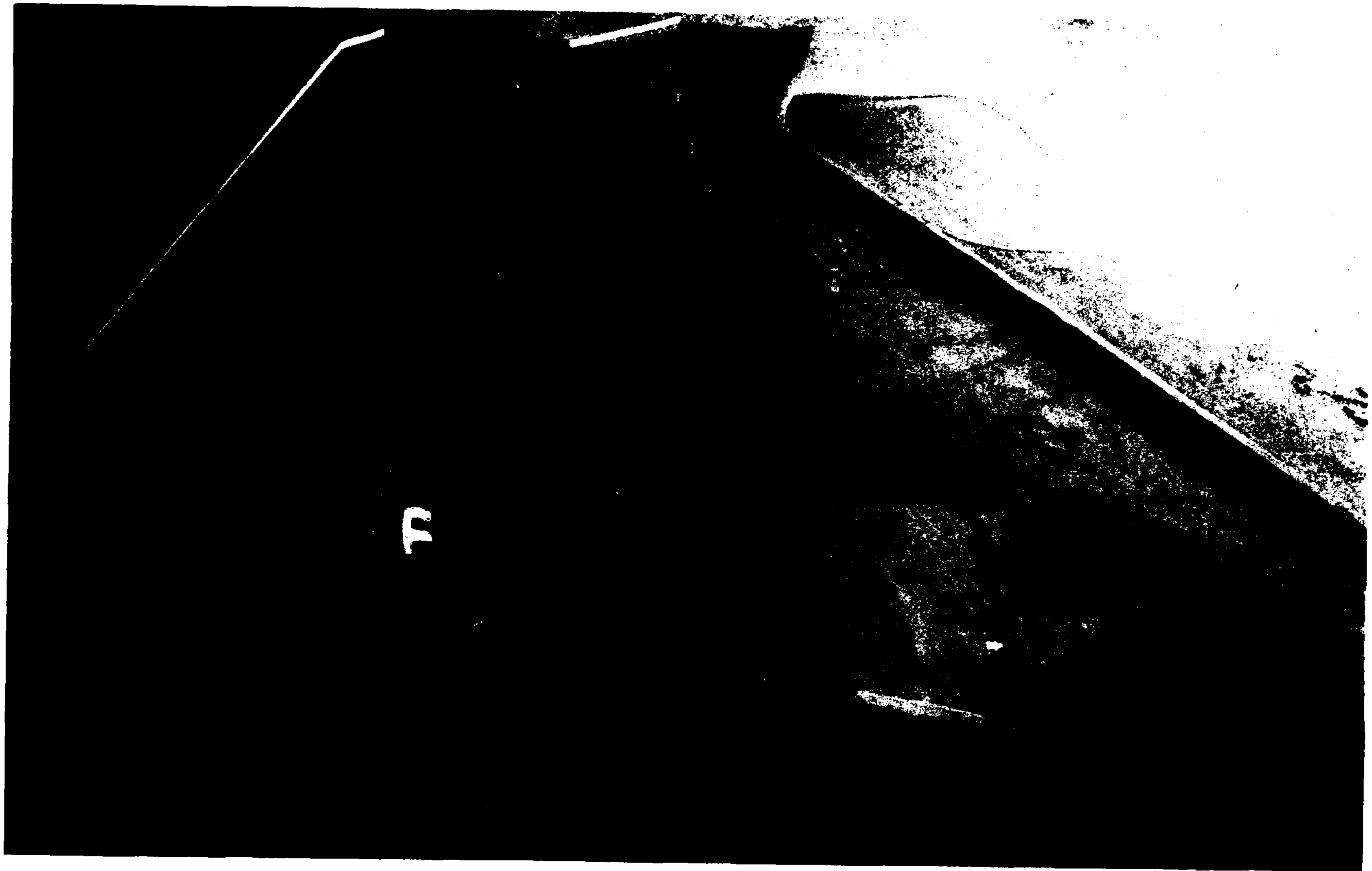


Photo 129. Wave patterns in the harbor due to boat wake 15 sec after the vessel began acceleration (leaving from the northeast corner)

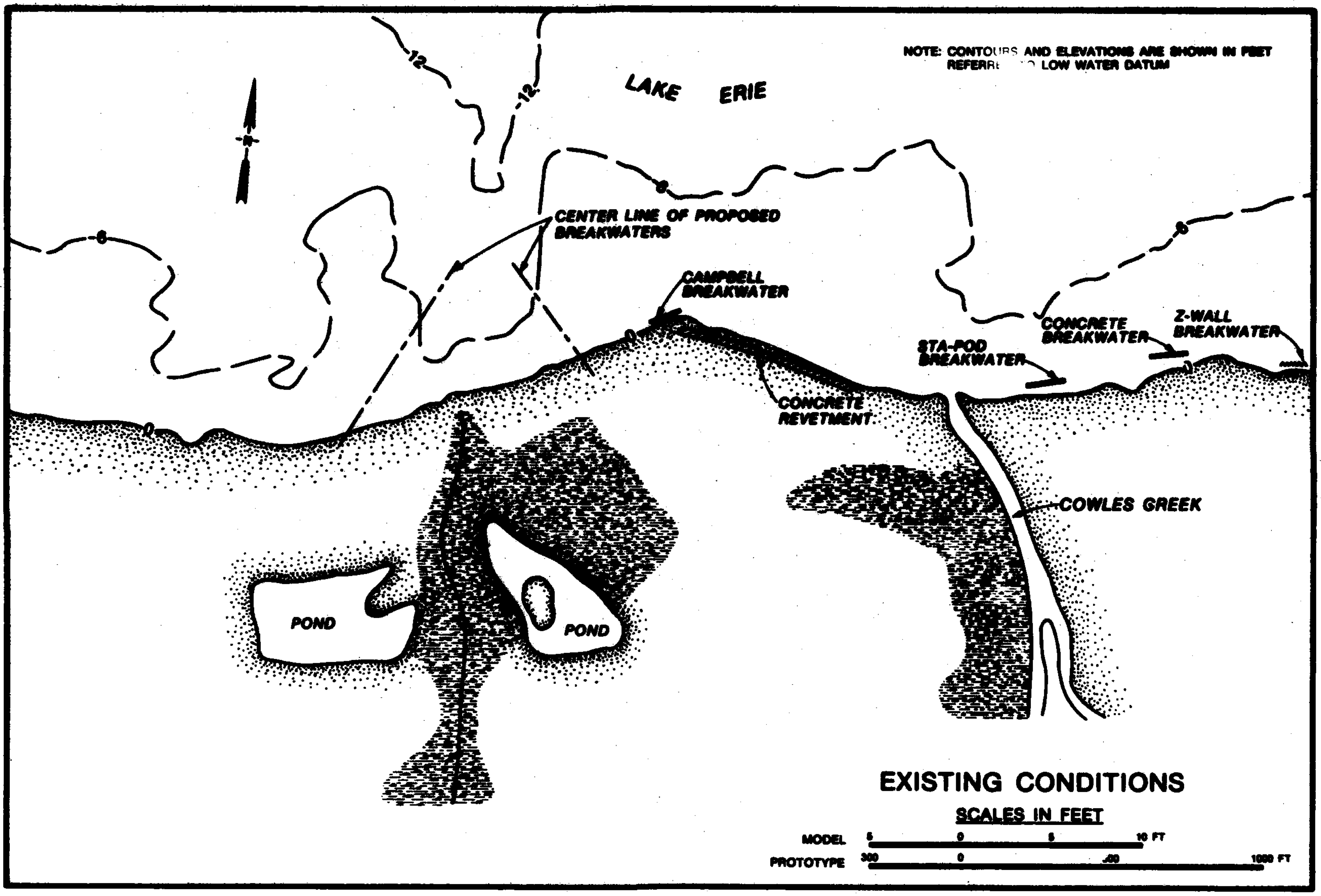
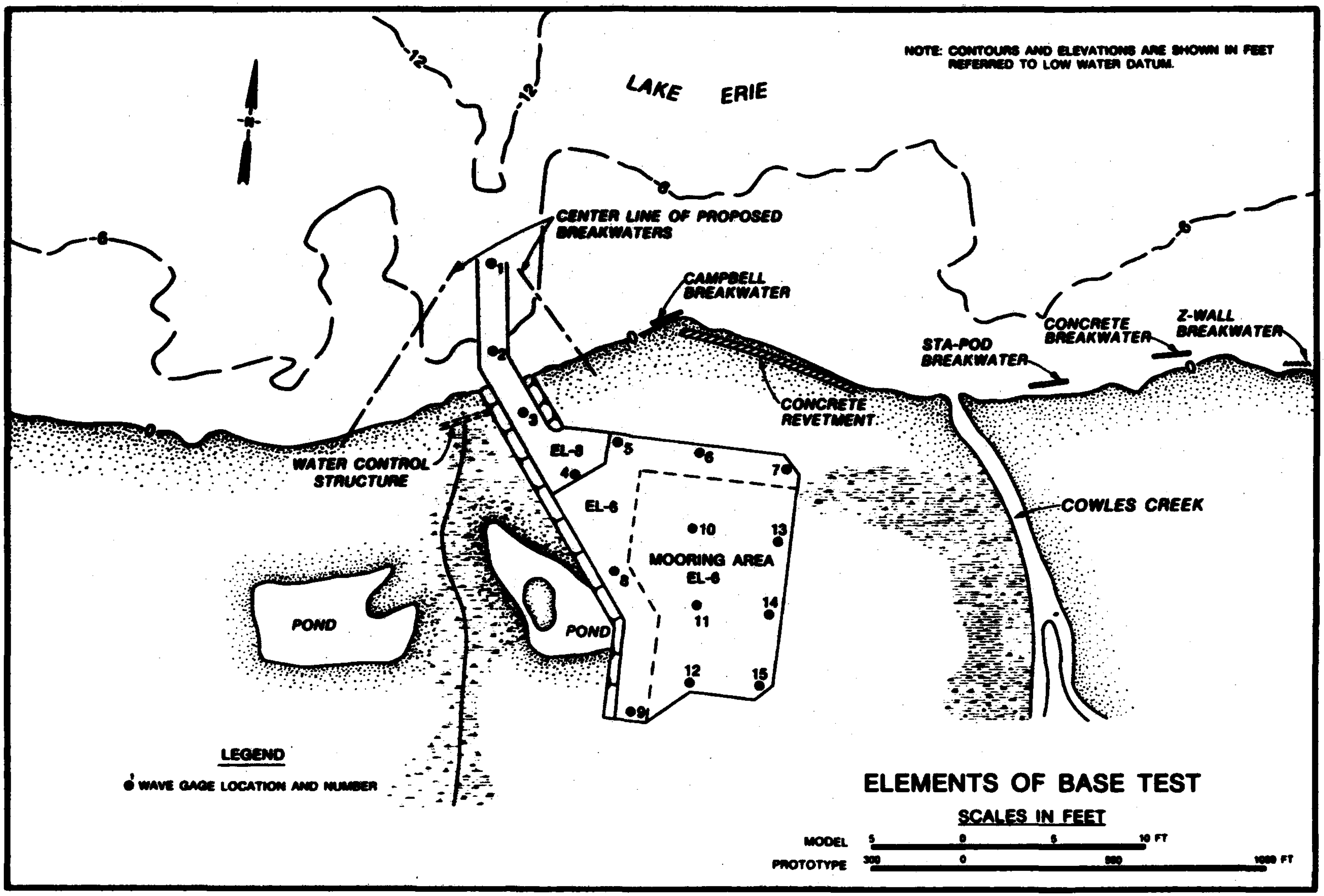
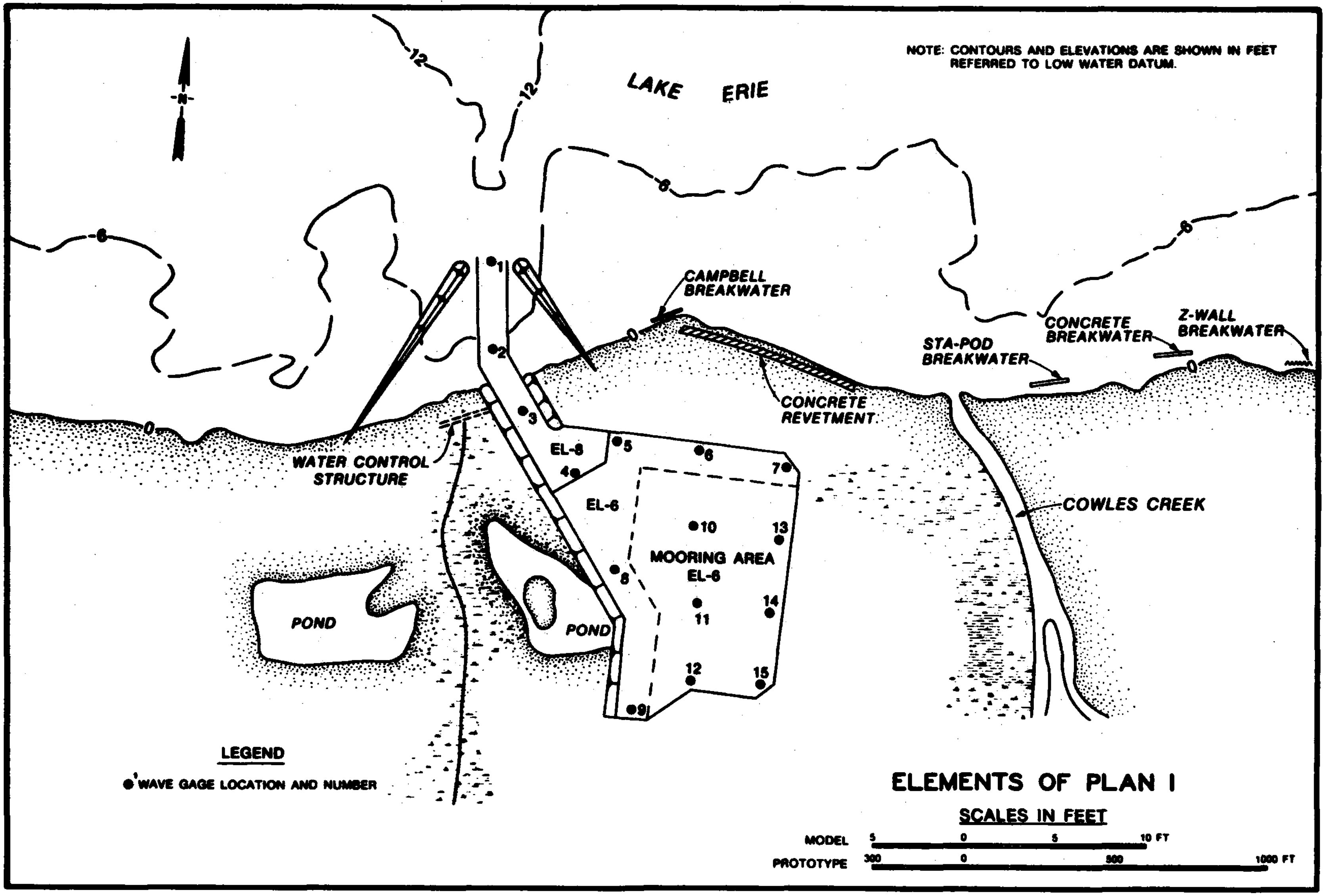

NOTE: CONTOURS AND ELEVATIONS ARE SHOWN IN FEET REFERRED TO LOW WATER DATUM
LAKE ERIE
12
12
6
6
6
0
0
0
CENTER LINE OF PROPOSED BREAKWATERS
CAMPBELL BREAKWATER
CONCRETE REVETMENT
STA-POD BREAKWATER
CONCRETE BREAKWATER
Z-WALL BREAKWATER
COWLES GREEK
POND
POND
EXISTING CONDITIONS
SCALES IN FEET
MODEL 5 0 5 10 FT
PROTOTYPE 300 0 500 1000 FT

PLATE 1

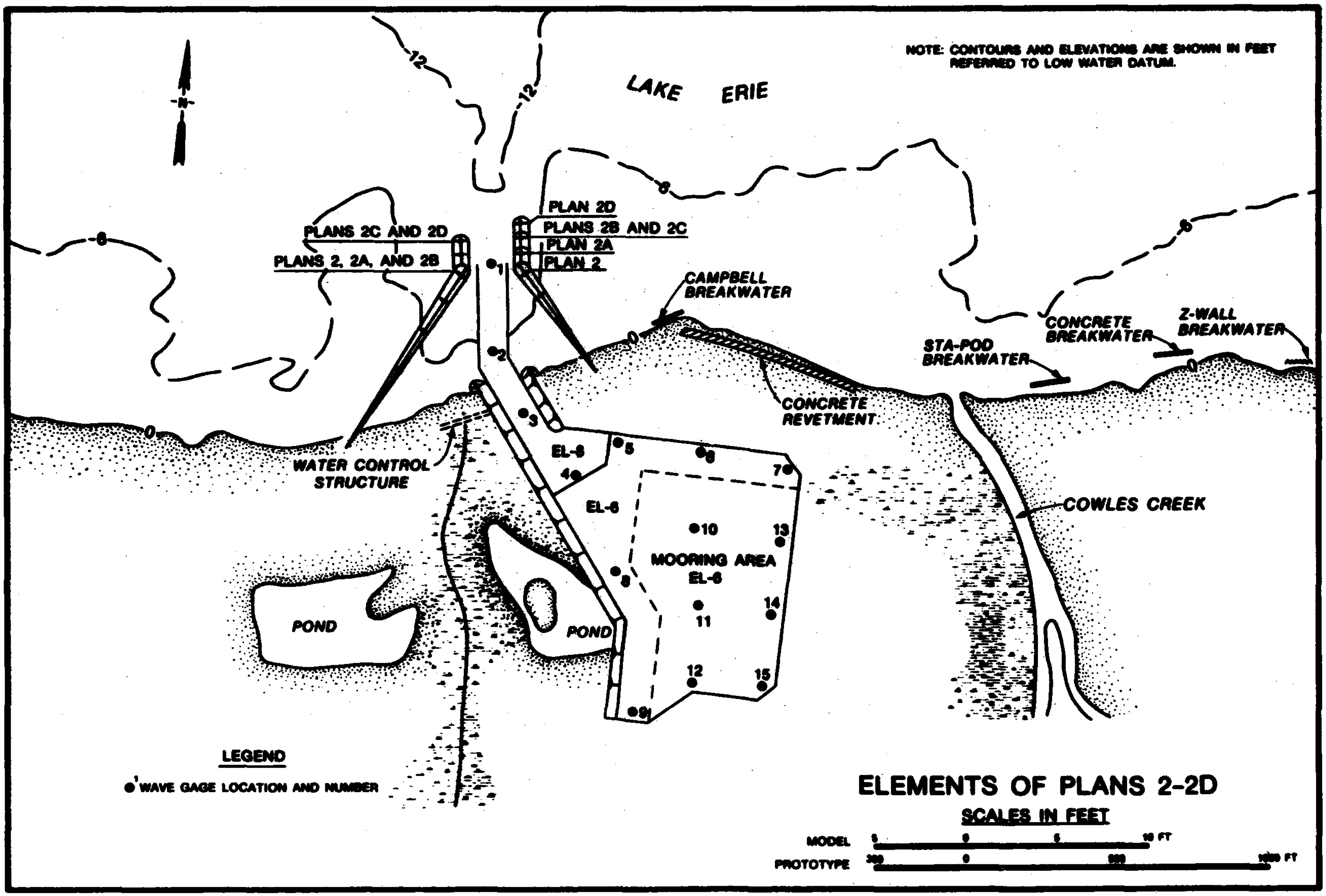
PLATE 2


NOTE: CONTOURS AND ELEVATIONS ARE SHOWN IN FEET REFERRED TO LOW WATER DATUM.
LAKE ERIE
CENTER LINE OF PROPOSED BREAKWATERS
CAMPBELL BREAKWATER
CONCRETE BREAKWATER
Z-WALL BREAKWATER
STA-POD BREAKWATER
CONCRETE REVETMENT
WATER CONTROL STRUCTURE
COWLES CREEK
EL-8
EL-6
MOORING AREA EL-6
POND
POND
LEGEND
WAVE GAGE LOCATION AND NUMBER
ELEMENTS OF BASE TEST
SCALES IN FEET
MODEL 5 0 5 10 FT
PROTOTYPE 300 0 500 1000 FT



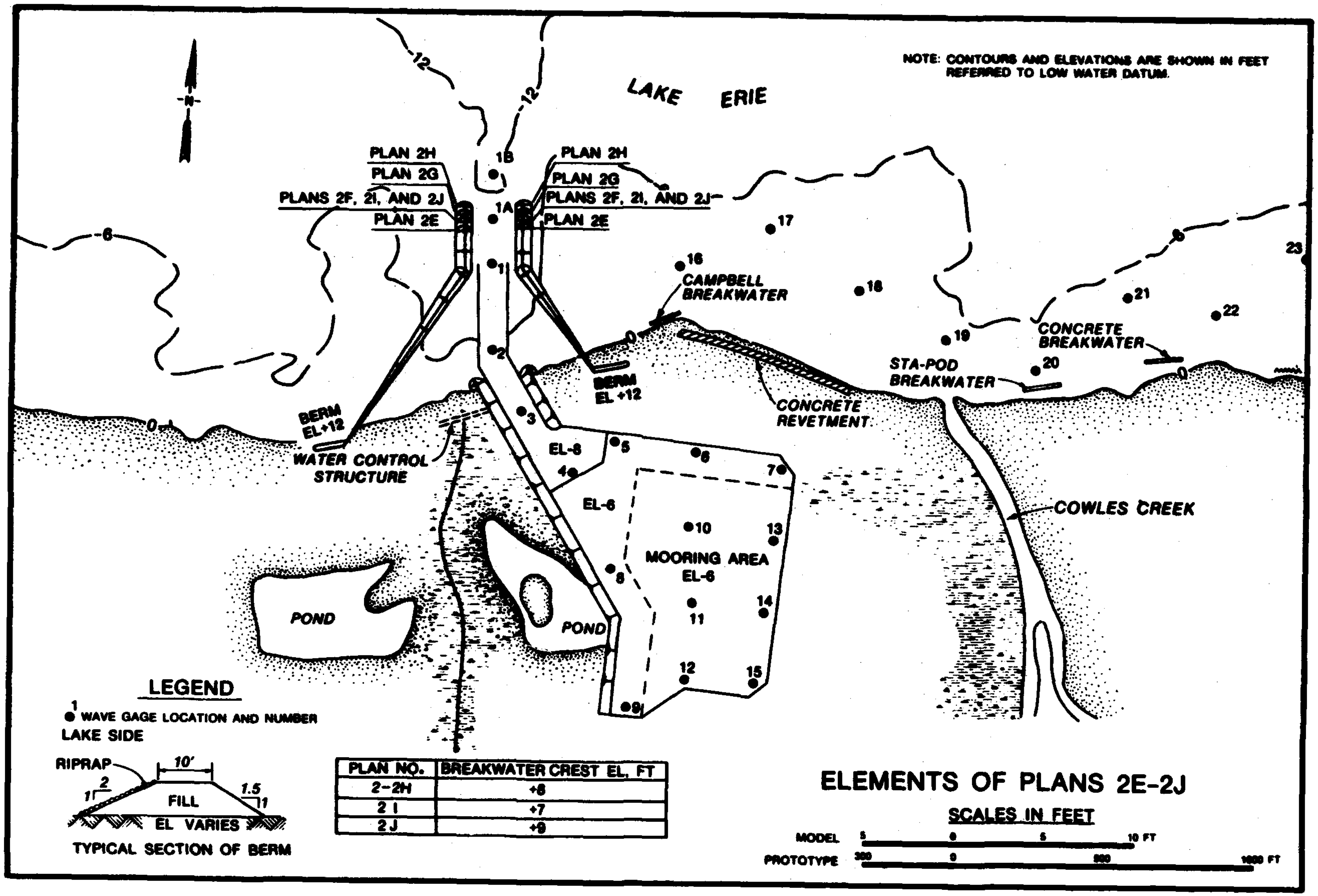
ELEMENTS OF PLAN I

PLATE 3



ELEMENTS OF PLANS 2-2D

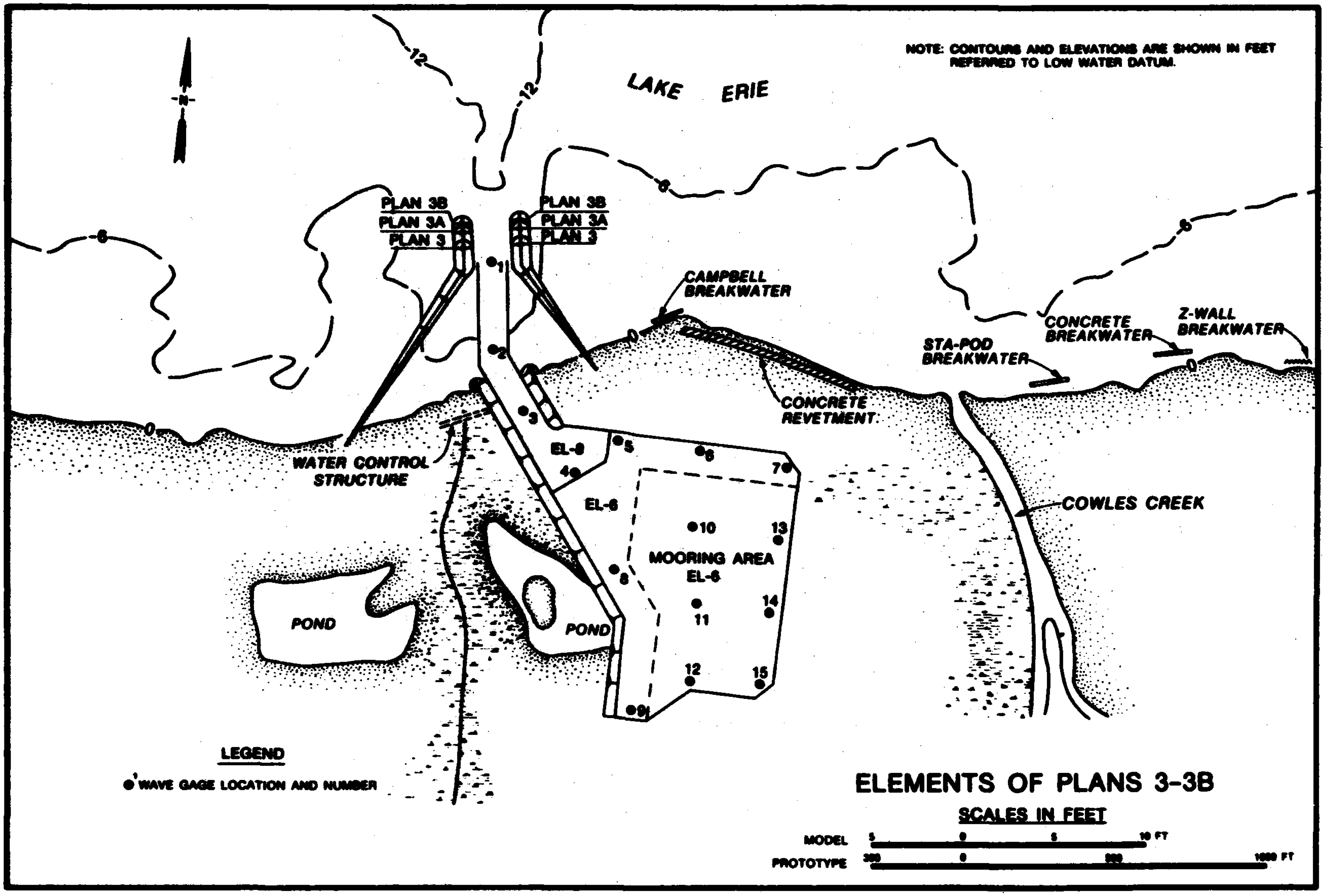
PLATE 4



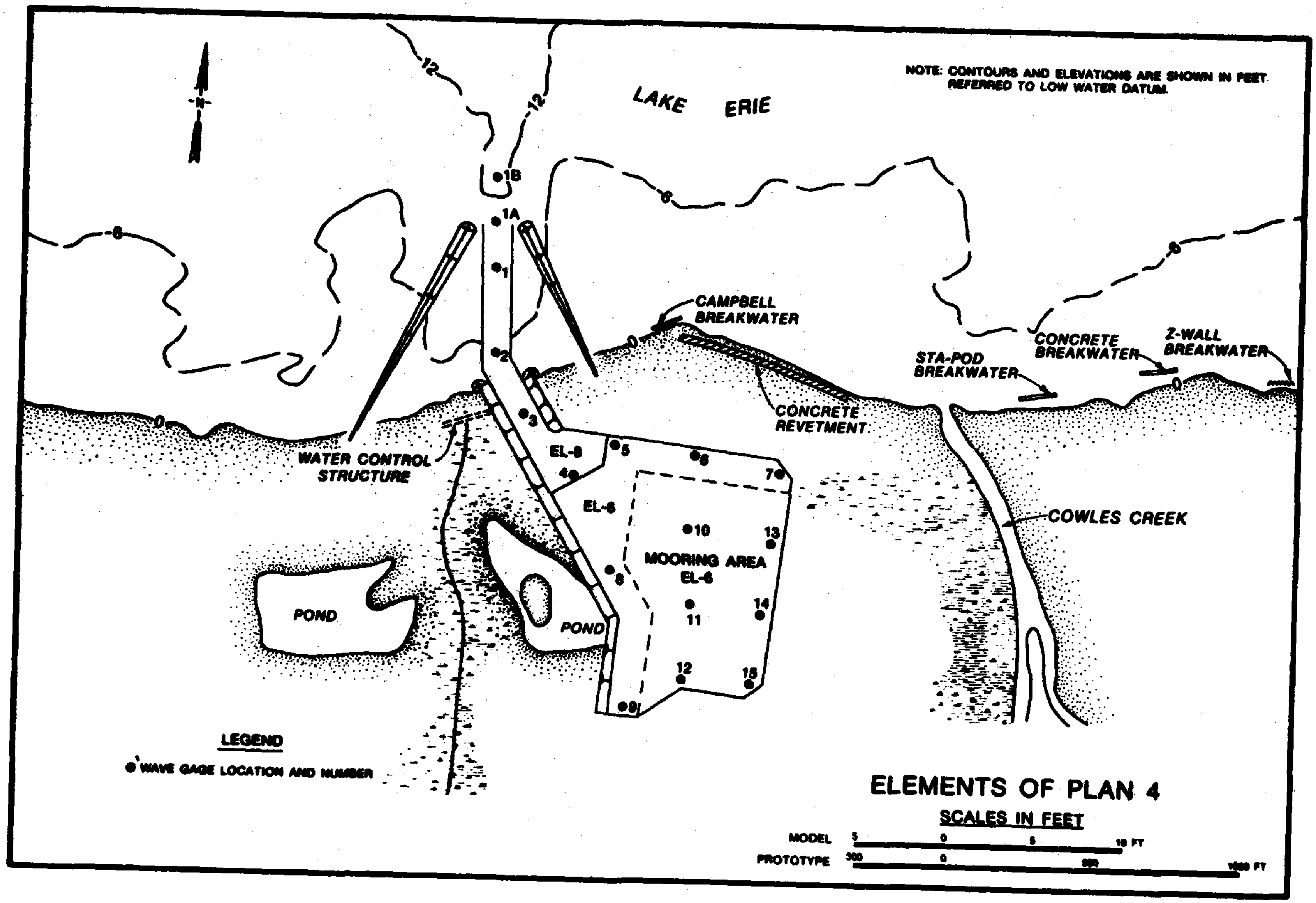
PLAN NO.	BREAKWATER CREST EL, FT
2-2H	+8
2 I	+7
2 J	+9

ELEMENTS OF PLANS 2E-2J

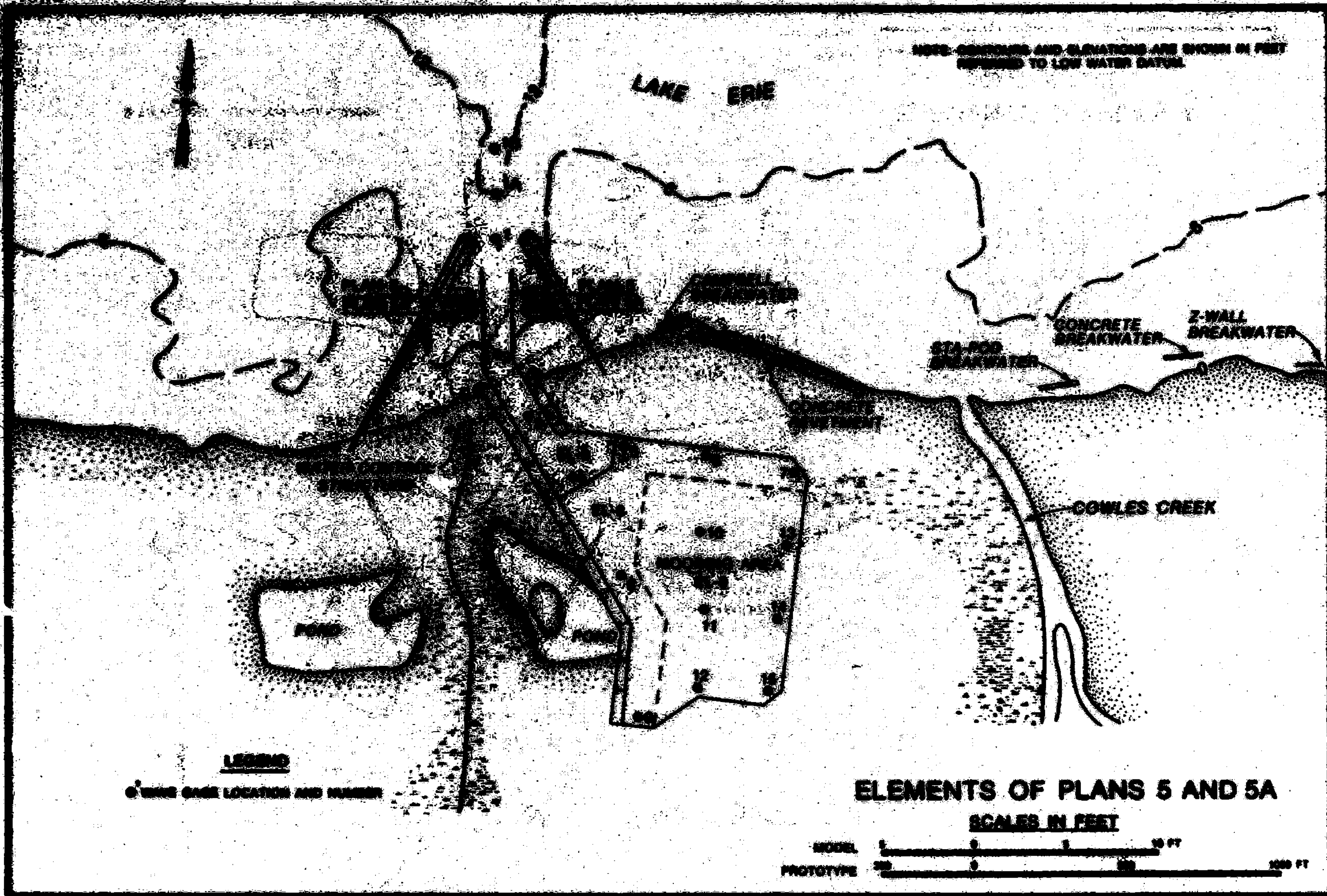
PLATE 5



ELEMENTS OF PLANS 3-3B



ELEMENTS OF PLAN 4


TO LOW WATER DATUM.
LAKE ERIE
CONCRETE BREAKWATER
Z-WALL BREAKWATER
STA-POD BREAKWATER
COWLES CREEK
LEGEND
ELEMENTS OF PLANS 5 AND 5A
SCALES IN FEET
MODEL
PROTOTYPE

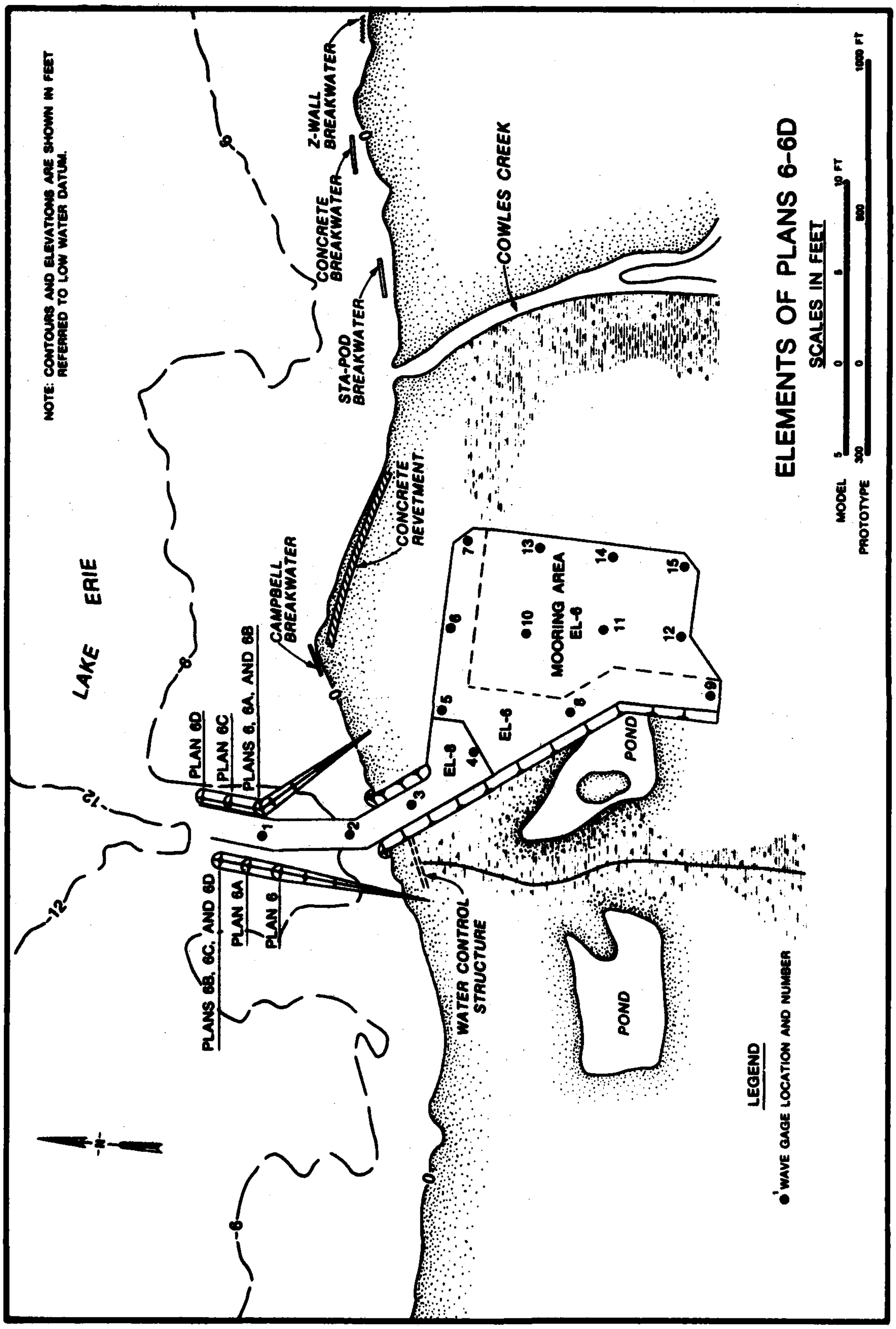
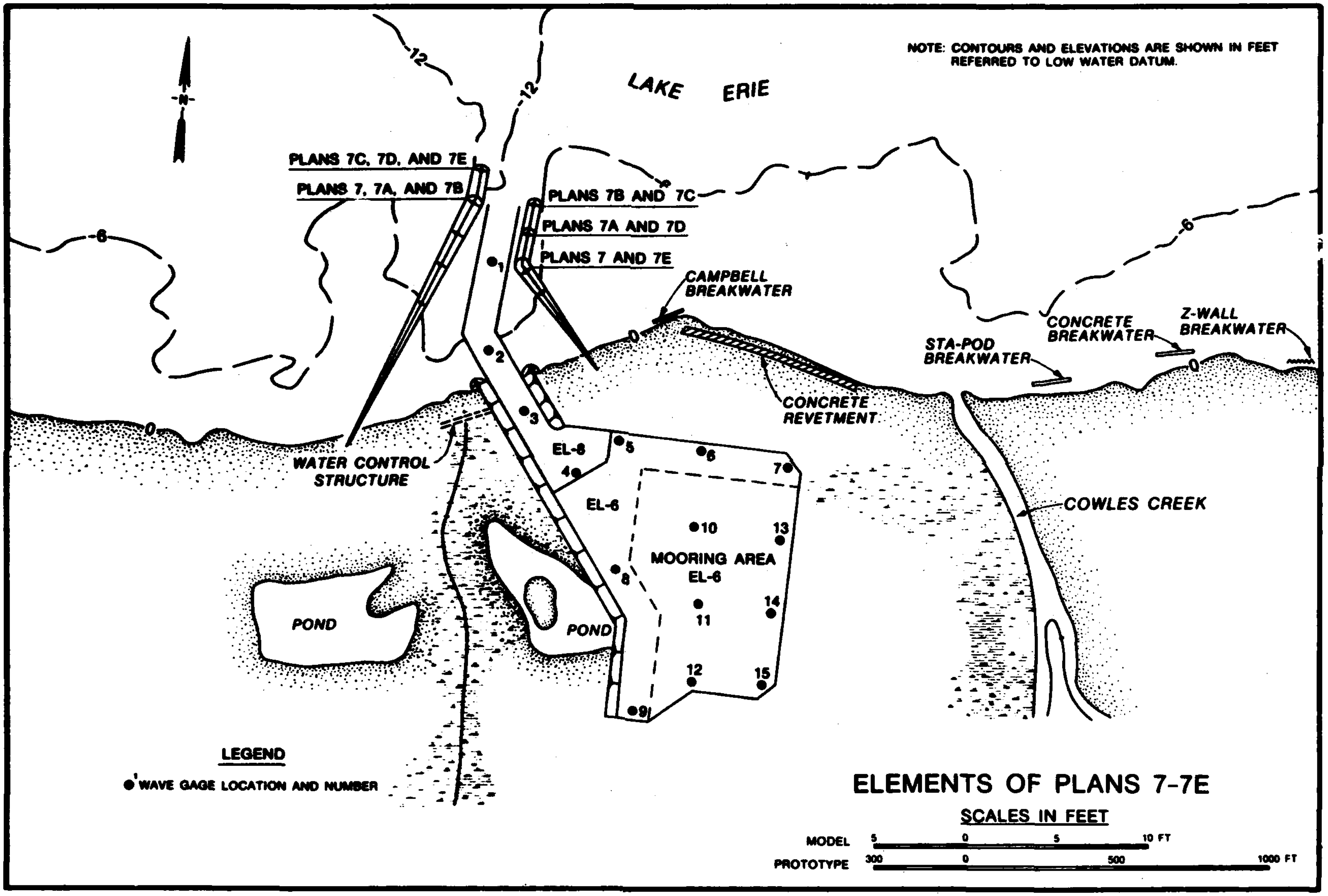
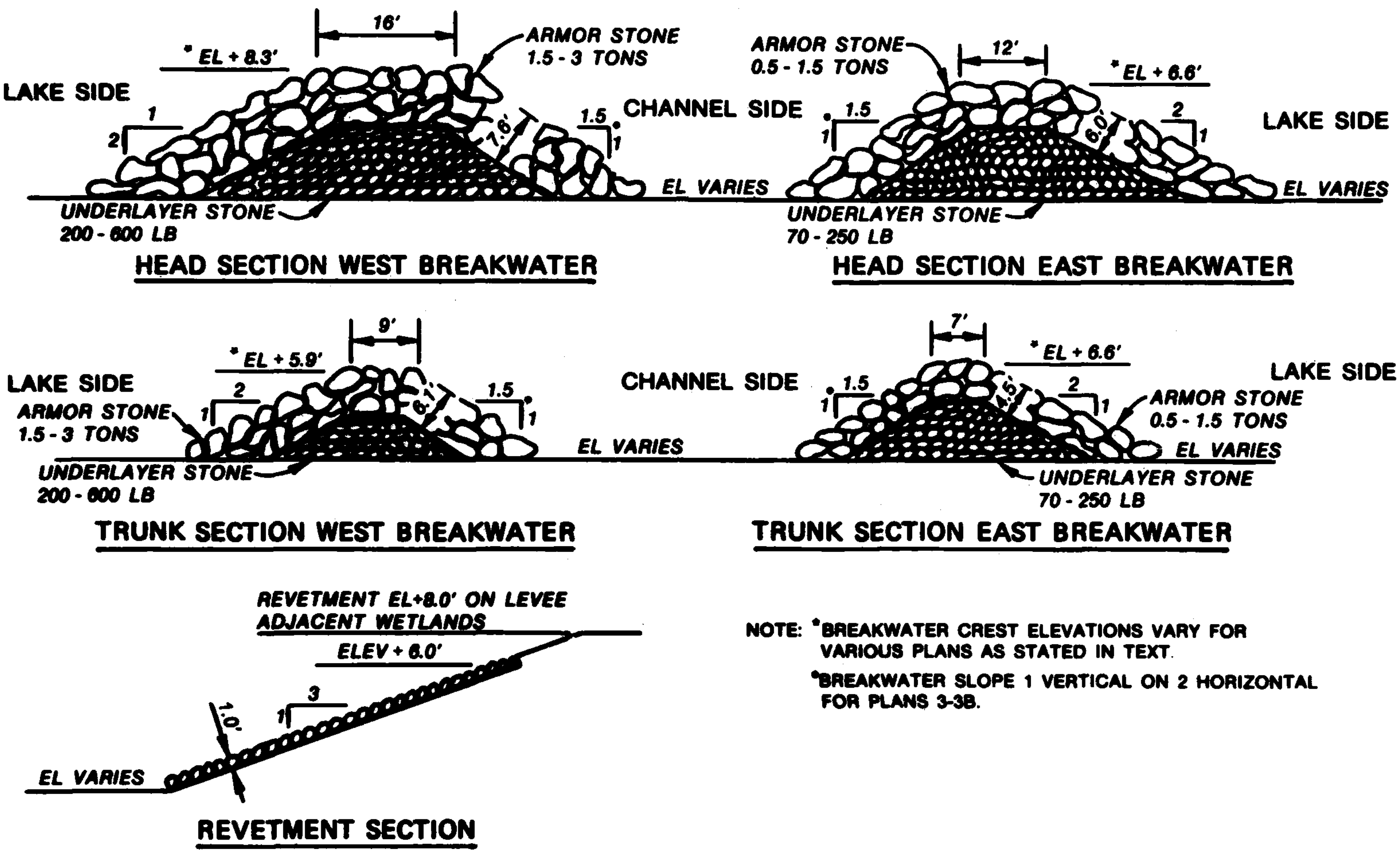

NOTE: CONTOURS AND ELEVATIONS ARE SHOWN IN FEET REFERRED TO LOW WATER DATUM.
LAKE ERIE
Z-WALL BREAKWATER
CONCRETE BREAKWATER
STA-POD BREAKWATER
COWLES CREEK
CONCRETE REVETMENT
CAMPBELL BREAKWATER
PLAN 6D
PLAN 6C
PLANS 6, 6A, AND 6B
PLANS 6B, 6C, AND 6D
PLAN 6A
PLAN 6
WATER CONTROL STRUCTURE
MOORING AREA EL-6
EL-6
EL-8
POND
POND
LEGEND
WAVE GAGE LOCATION AND NUMBER
ELEMENTS OF PLANS 6-6D
SCALES IN FEET
MODEL
PROTOTYPE

PLATE 9



ELEMENTS OF PLANS 7-7E

PLATE 10



NOTE: *BREAKWATER CREST ELEVATIONS VARY FOR VARIOUS PLANS AS STATED IN TEXT.

*BREAKWATER SLOPE 1 VERTICAL ON 2 HORIZONTAL FOR PLANS 3-3B.

TYPICAL BREAKWATER AND REVETMENT SECTIONS

APPENDIX A: NOTATION

A	Area
b	Shallow-water orthogonal spacing
b_o	Deepwater orthogonal spacing
$(b_o/b)^{1/2}$	Refraction coefficient, K_r
D_{50}	Median particle diameter
H	Shallow-water wave height
H_o	Deepwater wave height
$H_{1/3}$	Significant wave height
K_r	Refraction coefficient
K_s	Shoaling coefficient
L	Length
n	Manning's roughness coefficient
Q	Discharge
T	Time
V	Velocity
$\not{V}$	Volume
γ	Specific weight
γ'	Apparent specific weight
η_D	Ratio of median diameter particles
$\eta_{\gamma'}$	Ratio of apparent specific weights
λ	Horizontal scale
μ	Vertical scale

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Bottin, Robert R.
Design for wave protection and prevention of shoaling Geneva-on-the-Lake Small-boat Harbor, Ohio : hydraulic model investigation / by Robert R. Bottin, Jr. (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. ; available from NTIS, 1982.
204 p. in various pagings, 11 p. of plates ; ill. ; 27 cm. -- (Technical report ; HL-82-17)
Cover title.
"August 1982."
Final report.
"Prepared for U.S. Army Engineer District, Buffalo."
Bibliography: p. 42-43.

1. Erie, Lake. 2. Geneva-on-the-Lake Harbor (Ohio). 3. Harbors--Ohio. 4. Harbors of refuge. 5. Hydraulic models. 6. Shore protection. I. United States. Army. Corps of Engineers. Buffalo District. II. U.S. Army Engineer Waterways Experiment Station. Hydraulics

Bottin, Robert R.
Design for wave protection and prevention of : ... 1982.
(Card 2)

Laboratory. III. Title IV. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; HL-82-17.
TA7.W34 no.HL-82-17